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Hearing Conservation Program on a Campus: Worker Noise Exposure Assessment and Training

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Abstract

Introduction: Campus workers are exposed to loud noise from boilers, chillers, generators, snow blowers, leaf blowers, helicopters, utility vehicles, laboratory animals etc. No studies have looked at characterizing noise exposures among campus workers to see who needed to be enrolled in the Hearing Conservation Program (HCP).

Goal: The goal of this study was to determine which employees needed to be enrolled in a HCP.

Methods: This was a cross sectional study conducted among campus workers. We identified utility plant workers, comparative medicine workers, landscaping crew, security officers and facility staff who used utility vehicles as employees potentially exposed to excessive noise. We administered a questionnaire to understand workers' beliefs and attitudes towards their hearing conservation. In a second questionnaire, we collected non-occupational noise exposure and work history. We also performed area and full shift personal noise dosimetry sampling. Personal noise dosimetry data was compared to the National Institute for Occupational Safety and Health (NIOSH) Recommended Exposure Limit (REL), and the Occupational Safety and Health Administration's (OSHA) Action Level (AL) and Permissible Exposure Limit (PEL).

Results: Out of 76 employees, 30 volunteered to participate in the study. Twenty-seven volunteers (90%) responded to the questionnaires and all 30 participated in the personal dosimetry sampling. Ten employees responded that they used hearing protective devices (HPDs) around loud noise and 16 (61.5%) denied their use. Some examples of loud noise sources were generators (89.7 dB), reverse osmosis system (92.6 dB), Quinsv^{TM} compressor (92.3 dB) and backpack leaf blowers (92.6 dB).

Workers in four out of five departments exceeded the NIOSH REL of 85dBA. Workers in utility plants exceeded the OSHA AL as well.

Conclusion: Based on OSHA regulations, only utility plants workers should be enrolled in the HCP as they exceed OSHA AL. However, best practices dictate that workers in the utility plants, comparative medicine, and landscaping crew who exceeded the NIOSH REL also be enrolled in the hearing loss prevention program.

Impact of the Project: This project will protect campus workers from hearing loss by enrolling them in a hearing conservation program. The program will assess workers' exposures to noise, provide them an annual hearing test, and educate them on the selection and use of hearing protector devices.

Introduction

The National Institute for Occupational Safety and Health (NIOSH) estimates that more than 30 million American workers are exposed to hazardous noise every year. (Tak et al., 2009) Although noise is well characterized in mining, military, construction, agriculture, transportation, and manufacturing sectors (BLS, 2016), it is prevalent everywhere. High noise levels have been reported among animal shelter workers (Achutan 2007), New York City subways (Neitzel et al., 2006), sporting events (England et al., 2014) and in daycares (Koch et al., 2016).

Excessive exposure to noise leads to Noise Induced Hearing Loss (NIHL). Loud noise mechanically traumatizes and distorts hair cells in the epithelium of the cochlea and generates toxic reactive oxygen species (ROS). (Ladou and Harrison, 2014) The changes in these hair cells are reversible during initial exposures but continuous exposure replaces broken hair cells by the non-functioning scar tissue that causes permanent threshold shift. (Ladou and Harrison, 2014)

To protect workers, the Occupational Safety and Health Administration (OSHA) has set a Permissible Exposure Level (PEL) of 90 decibels over an 8-hour shift. (OSHA,1983) However, OSHA recognizes that this level is not adequate to protect workers' hearing. Therefore, OSHA developed an Action Level (AL) of 85 dB. OSHA requires employers to implement a Hearing Conservation Program (HCP) for employees whose full-shift exposures equal or exceed 85 dBA. NIOSH takes a more conservative and scientifically based approach to evaluate exposures in the workplace. It recommends employees to participate in a Hearing Loss Prevention Program (HLPP), if they meet or exceed an exposure to noise with an exposure of 85 dBA over eight hours. (NIOSH, 1998) This level is NIOSH's Recommended Exposure

Level (REL). Noise measurements are sometimes weighted. Because humans hear at the higher frequencies, noise measurements are typically A-weighted, which means that more weight is placed on the higher frequency sounds. (NIOSH, 1998) Therefore, the dB is denoted as dBA. The OSHA and NIOSH standards are expressed as dBA because these levels relate to human hearing. When measuring machinery noise, we use a C-weighted scale because we want to include some of the low frequency sounds. (NIOSH, 1998) These noise levels are denoted by dBC.

In addition to expressing as decibels, noise levels can also be expressed as percent dose. An employee is allowed 100% dose a day. An employee exposed to 200% dose has twice the daily allowable limit. The OSHA PEL of 90 dBA corresponds to 100% dose and the OSHA AL of 85 dBA is equivalent to 50% dose. (OSHA, 1983) The NIOSH REL of 85 dBA is equivalent to 100% dose. (NIOSH, 1998) Although the NIOSH REL and the OSHA AL are both 85 dBA, their percent doses differ because they are calculated based on different assumptions.

OSHA requires employers to enroll employees in a HCP who are at or above the OSHA AL (OSHA, 1983)

Noise levels

An HCP is a program designed to conserve an employee's hearing. It includes noise monitoring of the workplace, noise control, selection and use of hearing protection devices, audiometric monitoring, worker training, record keeping and program evaluation. (OSHA, 1983) The purpose of this study is to identify employees on an academic campus who need to be enrolled in a hearing conservation program (Appendix) through an assessment of their noise exposures.

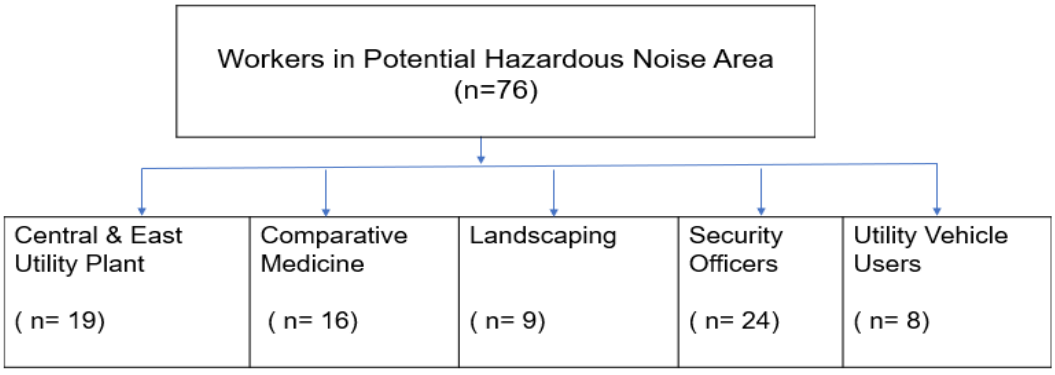
Methods

This was a cross sectional study conducted in a medical campus over sixteen months. Researchers collaborated with the campus Department of Environmental Health and Safety to identify workers who might be exposed to loud noise. We walked through multiple departments on the campus and identified boilers, chillers, compressors, generators, snow removals, leaf blowers, non-human primates, dirty cage-cleaners and helicopters as potential loud noise sources. Utility plant, landscaping and comparative medicine workers along with security officers and facility staff using utility vehicles were identified as a target population (n=76). Site supervisors were contacted via telephone and requested to communicate to the employees about the study. We visited these departments at the beginning of the shift and asked for volunteers. Every employee who was present had a chance to participate in the study. The shifts typically began at 7 a.m., 3 p.m., and 11 p.m. We included all 30 workers who volunteered in the study. Management members were excluded because they primarily did not work around potential noise sources. We administered questionnaires, performed area noise measurements and collected full-shift noise samples. Questionnaires were provided at the beginning of the shift and requested to complete by the end of the shift. Thirty seconds area noise samples were collected when the machines were running.

Participants and Work practices: Central Utility Plant (CUP) and East Utility Plant (EUP) power stations provided all the heating and cooling requirements on the campus and supplied emergency power in the event of power disruption. These two plants had a total of six dual fuel boilers, ten chillers, and seven emergency generators. In addition, the plant operated multiple water pumping machines, Quinsv™ compressor and reverse osmosis system. Nineteen employees worked

around these machineries on a full-time basis. Campus comparative medicine used animal models and performed biomedical and transitional research. Dirty and clean rack and tunnel washers and non-human primates holding rooms were identified as potential loud areas in this department. Sixteen employees worked in comparative medicine who rotated around multiple areas. Campus landscapers shoveled the snow in the winter and mowed lawns, trimmed shrubs and blew the dirt and leaves during spring and summer. These workers used snow remover, backpack leaf blower and lawn mower machines which were loud. There were eight full time staff and one temporary staff in this department. Security officers worked 24 hours a day, seven days a week, securing campus safety and two helipads. Security officers were exposed to loud noise during landing, hovering and taking off the helicopters. At least one security officer was scheduled to respond to the helipad per shift. There were 24 security officers on the campus. Campus facility staff used small utility vehicles; Gator vans and Kubotas for short distant transits. These vehicles were also used to transport materials from one location to another on the campus. These vehicles could be potential loud noise sources.

Fig.1: Population and Settings Summary



Questionnaires

The first questionnaire was based on the Health Belief Model (HBM) theory of health promotion and its six constructs: perceived susceptibility, perceived benefits, perceived barriers, perceived severity, social norms and self-efficacy (Hayden, 2009). Table 2 shows examples of questions under each construct. This questionnaire was originally developed by NIOSH and was used in a research study conducted among Swedish workers. (Svensson et al., 2004) The purpose of this questionnaire was to understand workers' beliefs and attitudes towards hearing conservation.

Noise exposure history

We also collected noise exposure and work history using a second questionnaire. We asked years of service in the campus, use of HPD around hazardous noise, exposure to non-occupational noise sources etc. We developed these questions based on the literature research.

Area noise measurement

Area noise samples were collected during normal operations when the machines were running. Samples were collected to minimize disruption to the workers; therefore, the sampling scheme used here was convenience and not random. Thirty seconds samples were taken in A- and C-weighted scales using a Larson Davis LxT1 (Depew, NY) sound level meter. Some machines were automatic and ran only when energy was needed. We walked through the departments multiple times to check if the machines were running. The area samples could represent overestimation of the exposure as machines were not constantly producing noise throughout the shift. Also, we were not able to understand if some of the machines were on full power. Machines

could be louder if energy demand was higher. Non-human primate room samples were collected during feeding time because workers suggested animals were loud during this time.

Personal noise measurement

Full shift personal noise dosimetry samples were collected by using Larson Davis Spark ™ 706 (Depew, NY) noise dosimeter. The dosimeter was hooked at the waist level and the microphone was placed at the shoulder level near the ears. Eight-hour time-weighted average (TWA) and percent dose were computed by the instrument and downloaded for additional analysis. The TWA and % doses were compared to the OSHA PEL (100% dose), OSHA AL (50% dose) and the NIOSH REL (100% dose).

Equivalent continuous sound level (Leq) and Lpeak (peak sound pressure) is used to demonstrate the area sampling data in this study. Leq is a preferred method to describe sound levels that fluctuate over time as it accounts for all sound energies exposed at that time and results in a single decibel. (Passchier-Vermeer & Passchier, 2000) Peak sound pressure is the highest instantaneous sound pressure during the time of sampling. (OSHA, 1983)

Results

Out of 76 employees, 30 volunteered to participate in the study. Twenty-seven employees (90%) responded to both questionnaires and all 30 volunteers participated in the personal dosimetry sampling. The majority of workers (92%) had more than one year of service on the campus; 54% worked for more than 5 years. Ten employees used HPDs around loud noise and 16 (61.5%) denied their use. Workers were also

exposed to non-occupational noise sources like power tools (63%), chain saw (63%), lawnmowers (81%), rock band and loud music (63%) and hunting and shooting (52%).

Most of the workers (>92%) agreed to adapt healthy behaviors to the questions related to Health Belief Model (HBM) constructs perceived susceptibility, perceived benefits, and perceived severity (Table 2). These constructs describe workers' belief about perceiving the risk of disease, understanding the benefits of interventions and identifying the disease as a big issue respectively. (Hayden, 2009) All workers believed that loud noise could hurt their hearing. These workers also believed that wearing HPD was important because it could protect their hearing from loud noise. Some of the workers (about 7%) believed exposure to loud noise eventually toughened ear and noise wouldn't damage their hearing any more. The majority of the workers believed hearing loss was serious disease. About 7% employees didn't perceive hearing loss as a big handicap or a problem.

On average, (32-42%) workers disagreed to adapt healthy behaviors for perceived barriers, social norms and self-efficacy HBM constructs. These constructs describe workers' belief about facing difficulties to use personal protective equipment, learning from other workers' behaviors and one's knowledge about the problem respectively. (Hayden, 2009) These workers believed that hearing protectors were difficult to wear (52%) or put too much pressure (26%). These workers (52%) thought they couldn't hear signals or beeps in the workplace when they wore hearing protection. Most of workers (96%) knew if ear plugs were fitting properly but some workers (30%) didn't know when to replace ear plugs. Workers (43%) also responded that their coworkers didn't care about hearing protectors and didn't wear hearing protectors (70%) around loud noise.

Table 2: Questionnaire results on attitudes and beliefs of campus workers towards hearing conservation.

Health Belief Model Constructs	Questions	Strongly Agree	Agree	Disagree	Strongly Disagree	Total
Perceived Barriers	I think earplugs put too much pressure on my ears.	2	5	15	4	26
Perceived Barriers	Hearing protectors are uncomfortable to wear.	3	10	12	2	27
Perceived Barriers	I think it will be hard to hear warning signals (like back-up beeps) if I am wearing hearing protectors.	7	7	13	0	27
Self-Efficacy	I believe I know how to fit and wear earplugs.	11	15	1	0	27
Self-Efficacy	I'm not sure how to tell when earplugs need to be replaced	1	7	17	2	27
Self-Efficacy	I know when I should use hearing protectors	9	17	1	0	27
Social Norms	Most of my coworkers do not wear earplugs, so I don't care about earplugs too.	0	4	17	6	27
Social Norms	Most of my co-workers think it is a good idea to wear hearing protectors in hazardous noise.	3	16	5	2	26
Social Norms	Most of my co-workers wear hearing protectors when they work around loud noise.	2	6	13	6	27
Perceived Susceptibility	I believe that my ears can eventually 'get toughened' to noise, so they are less likely to be damaged by it.	0	2	12	13	27
Perceived Susceptibility	I believe exposure to loud noise can hurt my hearing.	16	11	0	0	27
Perceived Susceptibility	I think I can work around loud noise without hurting my hearing.	1	3	17	6	27
Perceived Benefits	I am convinced I can prevent hearing loss by wearing hearing protectors whenever I work in loud noise	7	18	1	1	27
Perceived Benefits	If I wear hearing protection, I can protect my hearing.	13	14	0	0	27
Perceived Benefits	I think wearing hearing protectors every time I am working in loud noise is important	7	17	2	1	27
Perceived Severity	Losing my hearing would make it hard for people to talk to me.	11	13	2	1	27
Perceived Severity	I don't think it would be such a big handicap to lose part of my hearing.	1	2	13	11	27
Perceived Severity	I think it would be a big problem if I lost my hearing.	18	8	1	0	27

Table 3**:** Peak and equivalent continuous sound levels of Area Noise Samples by medical campus department and noise source.

Department	**Noise source**	**Sound levels** *(30-second samples)*	
		Leq (dB)	**LPeak (dB)**
Utility Plants	Boiler 1	81.8	95.3
	Boiler 2	82.6	95.8
	Transfer water pump	79.8	92.6
	Condensate pump	77.1	90.5
	Feed water pump	82.9	95.8
	Quinsv^{TM} compressor	92.3	104.3
	Reverse osmosis system	92.6	104.3
	Generator 1 east utility plant at start	88.0	104.7
	Generator 1 east utility plant at run	89.7	103.7
Ground Crew	Snow remover S 450 @ driver Seat	75.7	88.3
	Snow remover LS160 @ driver Seat	76.1	87.7
	Snow remover S 850 @ driver Seat	67.6	80.1
	Lawn mower	77.7	89.9
	Leaf blower backpack	92.6	104.7
	Leaf blower hand held	83.8	96.9
Utility Vehicle Users	Kubota utility vehicle (door open)	56.5	72.8
	Kubota utility vehicle (door closed)	67.2	75.9
	Kubota utility vehicle full power (uphill)	69.7	81.0
	Gators utility vehicle (door open)	78.8	94.4
	Gators utility vehicle (door closed)	71.1	113.8
	Gators utility vehicle full power at (uphill)	73.9	89.1
Comparative Medicine	Clean rack & tunnel washer	76.0	98.6
	Dirty rack & tunnel washer	75.5	96.1
	Non-human primates (Pig rooms)	82.3	101.2

- Equivalent continuous sound level (Leq) = Single decibel (dB) value of all fluctuating sound energies
- Peak sound level (Lpeak) = Highest sound pressure

Table 3 summarizes the area noise data collected in four of the 5 areas. Area noise sampling in utility plants showed equivalent sound level (Leq) ranging (77.1 dB- 92.6 dB) and peak sound level of 104.7 dB. Reverse osmosis system (92.6 dB), Quinsv^{TM} compressors (92.3 dB) and generators (89.7 dB) were the loudest noise sources in the utility plants. Backpack leaf blower used by the landscaping crew produced 92.6 dB with the peak sound level of 104.7 dB. Equivalent sound levels in comparative medicine and utility vehicles were not concerning, however, peak sound levels reached 101.2 dB and 113.8 dB respectively. There was a significant noise variation throughout the shift. This table could represent overestimation of the exposure. We were not able to identify if some of the machines were running with full power. These machines could be louder when there was a higher energy demand. Thus, these results may not represent the worst-case scenario as well.

Out of 30 workers, ten (33.3%) exceeded NIOSH REL and two exceeded OSHA AL. (Table 4) Noise dosimetry data showed utility plant, landscaping and comparative medicine workers and facility staff using utility vehicles exceeded the NIOSH REL. The majority of ground crew workers (83.3%) exceeded the NIOSH REL.

One of the facility staff who used the utility vehicles showed noise exposure of 96.2 dBA based on NIOSH assumption. This exposure was equivalent to 1249.5% compared to allowable limit of NIOSH REL (100% dose) for the day. However, this employee worked in the east utility plant generator room on the sampling day. The combination of two activities i.e. using utility vehicle and working in the east utility plant was found to be the highest noise exposure on the campus. Another employee who used a utility vehicle (85.2 dBA-NIOSH) worked in the central utility plant for most of the shift. Security officers' exposures were low (65.3- 75.2 dBA-NIOSH TWA), but we were not able to fully

characterize their exposures because we were not able to measure their exposures when working around helicopters.

Table 4: Full shift personal noise dosimetry samples by medical department

Department	Run Time (hours)	NIOSH TWA (dBA)	NIOSH Percent Dose (%)	OSHA PEL TWA (dBA)	OSHA PEL % Dose
Utility Plants	8.02	79.5	28.4	72.3	8.6
	8.05	80.2	33.1	73.4	10.0
	8.00	80.1	32.5	74.2	11.2
	7.47	79.4	25.6	72.6	9
	7.33	**86.6**	**132.7**	84.3	45.5
	7.50	**86.8**	**135.7**	**85.1**	**50.7**
Ground Crew	7.63	**85.2**	**100**	83.7	42
	7.88	84.6	89.8	79.6	23.6
	7.65	**90.6**	**348.7**	81	28.8
	7.72	**85.0**	96.5	79.3	22.8
	7.70	**87.1**	**156.4**	84.4	46
	7.73	**85.7**	**113.6**	81.2	29.4
Utility Vehicle Users	7.51	**96.2**	**1249.6**	**87.5**	**71**
	7.43	80.9	36	74.8	12.2
	8.15	**85.2**	**106.7**	76.2	14.8
	8.38	77.5	18.5	66.9	4.1
	8.20	82.5	57.5	76.8	16.1
	8.20	78.9	25	71.4	10.3
Comparative Medicine	7.17	81.1	36.6	77.1	16.7
	7.45	77.6	16.8	70.7	6.9
	8.18	**85.1**	**104.7**	82.4	34.9
	7.70	74.4	8.3	66.5	3.9
	8.05	84.2	83.6	76.8	16.0
	7.67	80.5	33.9	74.9	12.4
Security Officers	7.55	72.9	5.8	63.0	2.4
	7.88	75.2	10.3	66.4	3.8
	8.05	70.8	3.8	60.7	1.7
	7.33	69.3	2.4	60.3	1.6
	7.90	65.3	1.0	50.3	0.4
	7.62	67.2	1.6	54.9	0.8

- NIOSH TWA = Eight-hour Time Weighted Average (TWA) based on the National Institute for Occupational Safety and Health (NIOSH) Recommendation Exposure Limit (REL)
- NIOSH % Dose = Percent dose based on NIOSH REL (85 dBA = 100% dose)
- OSHA PEL TWA = Eight-hour TWA based on the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL)
- OSHA PEL % dose = Percent dose based on OSHA PEL (90 dBA = 100% dose)

Discussion

The Health Belief Model (HBM) can be used to understand workers' perception towards hearing conservation. This is important prior to implementing the hearing conservation program. If workers do not perceive the risk, the effectiveness of the program is going to be very low. Perceived susceptibility or risk is a perception to make workers adapt healthy behaviors. (Hayden, 2009) Hayden states the higher the perception of risk or susceptibility, the higher the probability of adapting the healthy behaviors. It is likely that campus workers would adapt healthy behaviors towards hearing conservation because greater than 92% of study participants perceived the risk of hearing as a major issue. Another approach of viewing the risk of NIHL is looking at the length of noise exposure on the campus and exposure to non-occupational noise sources. Workers (54%) had a long exposure to noise i.e. more than 5 years on the campus. The majority of these workers are also exposed to loud noise outside of work. This makes these workers more susceptible to NIHL.

There was a larger gap (on average 32-42% disagreed) among perceived barriers, social norm and self-efficacy constructs. These constructs describe workers' perceiving difficulties to use HPDs, adapting healthy behaviors by watching coworkers, and knowing when to replace the HPDs respectively. In one of the HBM question asked about their coworkers, 70% workers responded that other workers don't use HPD around loud noise. Workers (61.5%) also mentioned they don't use HPD around loud noise. It was observed that, there were two kinds of earplugs and one kind of earmuff offered to the employees. Providing a higher variety of hearing protectors could encourage employees to use them more often. Selecting a properly fitting comfortable HPD from many offered choices is more important than selecting a higher attenuating device. Studies recommended employers to provide varieties of

hearing protection devices so that workers can select HPDs based on comfort, fitting, and ease of handling. (Cesali and Park 1990; Royster and Royster 1990; Franks et al., 1996)

Although reverse osmosis system (92.6 dB), Quinsv^{TM} compressors (92.3 dB), generators (89.7 dB) and leaf blowers (92.6 dB) were different in size, construction and structure, the spot check results were found to be similar. Our results show that landscapers and utility plant workers are exposed to the loudest noise sources on the campus.

The highest personal noise exposure level (96.2 dBA) was measured on an employee who used a utility vehicle and worked around generators in the east utility plant. This exposure was equivalent to 1249% dose compared to allowable limit of NIOSH REL. This employee working in the generator room received 87.5 dBA OSHA PEL TWA (8) which is equivalent to 71% dose based on OSHA's assumption. Another employee who used the utility vehicle and exceeded the OSHA Action Level also worked in the central utility plant. Other four facility staff who used utility vehicles did not report being around louder noise sources. Thus, their exposures were low (77.5 dBA-82.5 dBA) Two of six employees (33%) who worked in the utility plants exceeded the NIOSH REL. These employees did not use any utility vehicles and were in the central utility plant for the day. An employee using utility vehicles exceeded OSHA AL only when they worked in the utility plants. Our results show that there is a higher NIHL risk for employees who work around running generators in the east utility plant. OSHA allows up to 90 dBA noise exposure within 8 hours without ear protection. (OSHA, 1983) But, OSHA also requires employers to implement hearing conservation program when the exposure is 85 dBA or above. Based on our results, the workers in the utility plants

must be enrolled in the hearing conservation program to comply with OSHA regulations.

Landscaping (83.3%) and comparative medicine (16.6%) workers exceeded NIOSH REL. Research studies have reported elevated noise levels from cage cleaning and high-power washing equipment. (Fox et al., 2015) The extent of hearing loss has not been reported among campus comparative medicine workers. The results in this study suggest that comparative medicine workers are at risk of NIHL. Workers rotated around hazardous noise sources in this department. These workers should be enrolled in the hearing loss prevention program as recommended by NIOSH. The noise exposure for landscaping workers were found to be slightly different from the exposures among other public universities. Researchers from North Carolina public universities found that noise exposures among landscapers exceeded the OSHA AL and were enrolled in the hearing conservation program (Balaney et al., 2016). In this campus, landscapers' personal exposure during winter (84.6-90.6 dBA) and spring (85.0-87.1 dBA) had similar results. These workers did not exceed OSHA AL in both seasons but exceeded NIOSH REL. OSHA does not require these workers to be enrolled in the hearing conservation program.

For best practices, this campus should consider NIOSH recommendations. The NIOSH standard is more protective because the standard is based on the physics of sound. (NIOSH, 1998)

The noise exposure caused by the helicopter could not be sampled as planned. During sampling days, helicopters were not provided. Therefore, we cannot conclude if security officers should be enrolled in an HCP. However, the noise exposure from the helicopters on the campus may pose a significant risk to the security officers. Prior studies suggest

that helicopters produce extremely loud noise. An exposure during helicopter operations could exceed OSHA PEL. (Kupper et al., 2004) This research was conducted among alpine helicopter rescue operation team, and suggests helicopters produce noise as loud as 114.9-120dB. An exposure for 21-30 minutes ranged from 90dBA-105dBA personal dose. A follow-up study is required to evaluate noise exposure among security officers on the campus helipad.

We recommend campus management to post signs in both entrance doors and inside generator room saying, “Noise Hazard Area- Ear Protection Must Be Worn at All Times”. Campus management is recommended to provide a higher variety of hearing protectors and reinforce their use.

Strengths and Limitations:

We were able to conduct noise exposure assessment on the campus. This baseline data was used to update the HCP. Employees who needed be enrolled in the HCP to comply with OSHA regulations were identified. Employees who were recommended to be enrolled in hearing loss protection program by NIOSH were also identified. The results from this study may not be generalizable as the study was conducted on only one convenience medical campus. We measured area samples only when machines were running. Since machines were on and off throughout the shift, the area samples might overestimate the exposure. We were not able to characterize the noise exposure from helicopters. A follow up study is required among security officers on the campus helipad. We did not select the participants randomly. Self-selection bias could be possible because of volunteer participants.

Conclusion

Our results show that the utility plant workers exceed OSHA AL of 85 dBA and should be enrolled in the hearing conservation program. Landscaping and comparative medicine workers do not exceed OSHA AL but exceed NIOSH REL. These workers are not required to be enrolled in the hearing conservation program by OSHA. But, these workers are recommended to be enrolled in hearing loss prevention program by NIOSH. Facility staff using utility vehicles need to be enrolled in the hearing conservation program only if they work in the utility plants. We were not able to fully characterize exposures to the security officers. A follow up study is required to characterize noise exposure on the campus helipad. The majority of the workers perceive NIHL as a serious issue on the campus and are likely to adapt healthy behaviors.

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Appendix

Hearing Conservation Program

Effective Date: 4/1/2018 (Draft)

Review Date:

Purpose:

The University of Nebraska Medical Center (UNMC) is committed to protecting the hearing of its employees who are exposed to hazardous noise at work. This program establishes the standards and requirements for compliance with federal regulations pertaining to hearing conservation of the UNMC employees. This hearing conservation program includes workplace noise monitoring, noise exposure controls, audiometric testing, hearing protection, training and motivation, recordkeeping and program evaluation.

The basis of this Program:

This program is based to comply with the Federal Occupational Safety and Health Administration (OSHA) standard found at 29 Code of Federal Regulations [CFR] 1910.95. OSHA requires all employers in the United States shall administer a continuing hearing conservation program whenever employee noise exposures equal or exceed an 8-hour time-weighted average sound (TWA) level of 85 decibels measured on the A scale (slow response) or, equivalently, a dose of fifty percent (50%) of OSHA Permissible Exposure Limit (PEL).

Applicability:

This Standard applies to all UNMC employees present in the areas with hazardous noise levels at or exceeding an 8-hour time-weighted average (TWA) of 85dBA. Students, faculty, staff, contractors, vendors, suppliers and visitors with occasional exposure shall also be required to wear hearing protection when they are in the areas with hazardous noise levels. However, these will not be included in the hearing conservation program (HCP).

Roles and Responsibilities:

Safety Manager:

The HCP is housed in the Department of Environmental Health and Safety. The UNMC Safety Manager shall be responsible for the overall administration of the Hearing Conservation Program. Specific responsibilities of the Safety Manager will include:

- Updating the hearing conservation program annually
- Ensuring noise monitoring is completed in the areas of concern periodically and when there is a change in production, process, equipment or increases exposure
- Ensuring that all hearing protection devices offer proper attenuation
- Ensuring initial and annual training is completed for all employees who work in the areas of concern
- Ensuring noise levels are posted in the locations in the facility as required by the OSHA Standard CFR 1910.95 Occupational Noise Exposure.

Hearing Conservation Trainer:

The hearing conservation trainer shall be responsible for:

- Ensuring initial and annual training are completed and records are forwarded to the UNMC Department of Environmental Health & Safety
- Ensuring UNMC employees are instructed on the proper use of hearing protection prior to entering the areas with hazardous noise
- Performing area noise survey and personal dose monitoring as required to comply with OSHA regulations
- Creating a training program and updating as required

Industrial Engineer and/or Maintenance Manager

Industrial Engineer and/or Maintenance Manager shall be responsible for:

- Assisting UNMC Department of Environmental Health & Safety by providing engineering controls to eliminate the hazardous noise levels
- Informing the UNMC Safety Manager for any structural/ constructional changes in the areas of concern and assist if a re-examination of noise levels is required

Area Managers and/or Supervisors

The Manager and/or Supervisor working for UNMC are responsible for:

- Reporting any potential noise hazards in any new area to the facility Safety Manager
- Ensuring that their direct reports are participating in the annual hearing conservation training and annual audiometric testing
- Enforcing the use of hearing protection devices among their direct reports and visitors in their area

UNMC Employees

UNMC employees who are required to participate in the annual hearing conservation program are responsible are:

- Wearing hearing protection devices as instructed
- Ensuring their hearing protective device fits properly and report to the department supervisor or safety manager if proper hearing protection devices are unavailable
- Completing initial and annual hearing conservation training
- Completing annual audiometric testing
- Following the instructions of UNMC Department of Environmental Health and Safety or audiologists if the standard threshold (STS) is confirmed

Elements of Hearing Conservation Program:

This written hearing conservation plan serves as a record of the details of the hearing conservation program for UNMC. We have this program in place to protect the hearing of all workers in UNMC. Elements of the hearing conservation program include:

- Noise monitoring
- Audiometric testing program
- Hearing Protection
- Training & Motivation
- Recordkeeping
- Program Evaluation

Noise Monitoring

UNMC Department of Environmental Health & Safety uses the equipment that is maintained and calibrated by the College of Public Health as a part of the safety partnership program.

Area surveys:

As a part of the monitoring process, area noise surveys shall be performed using the American National Standards Institute (ANSI) Sound Level Meter (SLM) with A-weighting and slow response settings. The SLM can be obtained from the program partners in the college of public health. The SLM shall be calibrated according to the user's manual. Equipment should be set to include all the noise from 80 dB- 130 dB in A weighted slow response setting.

The area survey will include UNMC as a facility, department names, make model/serial number of the survey meter (City, State), calibration date, and instrument settings.

Personal dose monitoring:

Each area with noise levels suspected to be more than 85dB or if verified by the area noise survey, personal noise exposure monitoring will be conducted. To conduct a personal dose monitoring, a small dosimetry device that is connected to a microphone will be hooked in the employee's waist level. The microphone is placed in the employee's shoulder level by the ear. This device will run for the whole shift and 8hr TWA is calculated. Personal dosimetry method will capture all the variable noise through the shift and covert into a single decibel value (dB).

Workers with Time-Weighted exposures at or exceeding 85 dBA as personal dose must be identified for inclusion in the hearing conservation program and must use hearing protection device.

Signs should be posted to show where high noise areas (above 85 decibels on an 8-hour TWA) among all UNMC departments. The sign will indicate that hearing protection is required. UNMC will notify all employees exposed at or above an 8-hour time-weighted average of 85 dBA of the results of the monitoring by providing a written notice.

Personal noise dosimetry will be repeated whenever there is any change in process, machinery or constructional /structural changes etc. that could alter the noise exposure.

UNMC will use OSHA's G-16 table of permissible noise exposure to reduce the noise exposure among employees.

TABLE G-16 - PERMISSIBLE NOISE EXPOSURES (1)

Duration per day, hours	Sound level dBA slow response
8	90
6	92
4	95
3	97
2	100
1 1/2	102
1	105
1/2	110
1/4 or less	115

Audiometric Testing Program

Audiometric testing provides information to analyze the employees hearing, pattern of hearing loss over time and also helps to understand how UNMC need to educate employees about their hearing loss. The audiometric testing program plays important role in employee's hearing protection.

The program ensures that a valid baseline audiogram is established for exposed employees within 6 months of their first exposure (or within one year if mobile vans are used, with employees wearing hearing protection for any period exceeding six months) and annual audiometric testing thereafter within one year.

- Currently, audiometric testing will be conducted in UNMC Eye, Nose & Throat (ENT) clinic by UNMC audiologists at no cost to the employees
- If the baseline audiogram was taken before the hearing conservation program took effect in 1983, it will be accepted if the professional supervisor or UNMC audiologist determines that the audiogram is valid
- Employees should not be exposed to workplace noise for 14 hours before the baseline test or must wear hearing protectors during this time period
- Baseline or annual audiogram must be conducted in a quiet room with no noise present

Audiometric testing is repeated annually. This will help UNMC to exercise the implementation of hearing protective measures before employees start losing hearing. UNMC compares annual audiograms to baseline audiograms to determine whether the audiogram is valid and whether the employee has lost hearing ability or experienced a standard threshold shift (STS). An STS is an average shift in either ear of 10 dB or more at 2,000, 3,000, and 4,000 Hertz. Noise-induced hearing loss can be temporary or permanent depending on the situation. A temporary hearing loss returns after a period of rest. Continuous exposure to a high-level sound causes damage to the hair cells in the inner ear which might result in a permanent STS. UNMC will provide the results of the non-STS audiometric testing in writing to all employees upon request. If the employee suffered a permanent STS, the result will be provided to the employee in writing.

Based on the examination result of the audiometric testing, UNMC will determine if standard threshold shift has occurred. As defined by OSHA on 29 CFR 1910.95(g)(10)(i), standard threshold shift (STS) is a change in hearing threshold, relative to the baseline audiogram for that employee, of an average of 10 decibels (dB) or more at 2000, 3000, and 4000 hertz (Hz) in one or both ears. The minimum sound dB an employee can hear should be 25dB or above to be considered an STS during the baseline study. If these criteria are fulfilled, this is an indication of a noise-induced hearing loss. If the employee has confirmed STS, UNMC is obligated to

- Fit or refit hearing protecting device to the employee, show them how to use them and enforce them to use hearing protection device.
- Notify employees within 21 days if it was determined that the audiometric test results show an STS.

If the annual audiogram reveals an STS, it should be compared with baseline audiogram. A validation test may be conducted. If the validation test identifies an STS, a re-test will be conducted within 30 days. If re-test conducted within 30 days reveals an STS, it is considered as the permanent STS and should be recorded in OSHA 300 log of injury or illness for UNMC within 7 days.

If subsequent audiometric testing of an employee whose exposure to noise is less than an 8-hour (time-weighted average) TWA of 85 dBA indicates a standard threshold shift is not persistent, UNMC informs the employee of the new audiometric interpretation by providing a written notice and employee may discontinue the required use of hearing protectors for that employee.

To determine the work-related hearing loss STS, UNMC Department of Environmental Health & Safety may request additional procedures with the UNMC ENT clinic referring to the audiologist. If additional testing is necessary or if UNMC suspects a medical pathology of the ear that is caused or aggravated by wearing hearing protectors, UNMC will refer the employee for a clinical audiological evaluation or otological exam, as appropriate from the ENT clinic.

Hearing Protection

UNMC will first attempt to determine the feasibility of using engineering and administrative control measures to decrease noise levels. When effective engineering or administrative controls are not feasible, hearing protection will be used.

UNMC provides hearing protectors i.e. ear plugs or ear muffs which are available to each affected employee exposed to an 8-hour time-weighted average of 85 dBA or greater at no cost to the employee. Hearing protection will be available in the department/shop and can be reordered or replaced as needed by the department supervisors.

The department should ensure that employees have a variety of suitable protectors that attenuate (lower) employee exposure at least to an 8-hour time-weighted of 85 decibels or lower for all employees.

UNMC ensures evaluation for adequacy of the hearing protection attenuation for the specific noise environments in which the protector will be used by using the Noise Reduction Rating (NRR) value.

Noise reduction rating (NRR) is a standardized format for all hearing protectors distributed in the U.S as published by the U.S. Environmental Protection Agency in 1979. The higher the NRR, the better attenuation is described if hearing protective device is worn effectively.

UNMC will follow following method to describe the accurate attenuation for hearing conservation device.

True decibel reduction = (NRR-7)/2

i.e. if the NRR printed on an earplug is 27 dB, it will be able to reduce the noise exposure by (27-7)/2 = 10 dB. This earplug can be used for work environment which has noise exposure up to 94 dBA, as our goal is to reduce the noise exposure below 85 dBA. This applies only if the earplug is worn effectively as trained by the hearing protection trainer.

If two hearing protection devices are used i.e. ear plugs and ear muffs, the method used above will be used taking the device with higher NRR and additional 5 dBA protection will be considered regardless the value of NRR for the second hearing protection device.

Example: The employee used a 27dB earplug and earmuff of NRR lower than 27dB. The total protection will be considered a 10dB +5 dB = 15 dB. This set up can be used in the work environment up to 99dBA personal dosimetry exposure to reduce the exposure below 85 dBA.

UNMC will reevaluate attenuation whenever employee noise exposures increase to the extent that current hearing protectors no longer provide adequate attenuation, and then provides more effective hearing protection by consulting college of public health hearing conservation program partners.

Training and Motivation

University of Nebraska Medical Center has instituted a hearing protection training program for each employee exposed to noise at or above an 8-hour time-weighted average of 85 decibels.

UNMC ensures employee participation in the hearing protection training program initially (baseline) during hiring and annually. Training will be provided by hearing conservation trainer or online as applicable. Training will be scheduled and those employees not completing the required training will be reported to the department supervisor for follow-up and actions.

UNMC repeats the training program annually. UNMC assures that the training material is updated to be consistent with changes in the protective equipment and work processes. The program will be reviewed annually in conjunction as a part of the College of Public Health Partnership program.

At a minimum, hearing conservation training will contain the following:

- The effects of noise on hearing
- The purpose of hearing protectors
- Advantages, disadvantages, and attenuation of various types of hearing protection
- General requirements of the OSHA 1910.95 Noise Standard
- Instructions on selection, fitting, use, and care of hearing the protection device
- The purpose of the audiometric testing, and an explanation of test procedures.
- Future access to the records

Recordkeeping

Recordkeeping is an essential element of the hearing conservation program since it is the means by which hearing levels are tracked and assessed over a period of years.

UNMC maintains accurate records of employee exposure measurements by storing the exposure measurements electronically in the Department of Environmental Health & Safety.

The audiometric test records meeting the requirements of this standard will be kept by the Employee Health.

UNMC retains noise exposure measurement records for at least 2 years. The ENT clinic will keep audiometric test records for employees. Audiometric test records for affected employees will be kept for the duration of employment at a minimum.

UNMC provides access to records to employees, former employees, representatives designated by the individual employee, and OSHA, upon request. The UNMC Department of Environmental Health and Safety Office will coordinate requests by contacting Human Resources and Employee Health.

In addition, when an employee experiences a standard threshold shift, the standard threshold shift is work-related, and the employee's total hearing loss equals or exceeds 25 dB from audiometric test on the same ear(s) as the standard threshold shift, then the hearing loss case must be recorded on the OSHA 300 Log, in accordance with 29 CFR 1904 as mentioned above.

Effective January 1, 2003, UNMC is required to record work-related hearing loss cases when an employee's hearing test shows a marked decrease in overall hearing by OSHA. This will allow UNMC to be able to make adjustments for hearing loss caused by aging, seek the advice of a physician or licensed health-care professional to determine if the loss is work-related and perform additional hearing tests to verify the persistence of the hearing loss as indicated in OSHA guidelines.

Program Evaluation

UNMC Department of Environmental Health and Safety will verify that the hearing conservation program has been implemented in all departments. On an annual basis, HCP should be evaluated to identify the gaps. This will help UNMC to understand the shortcomings and look for the opportunities to improve.

UNMC Noise Area Samples survey results

Company	University of Nebraska Medical Center
Make & Model of the Equipment:	Larson Davis LxT1 (SN: 0002468) sound level meter & Larson Davis Spark TM 706 noise dosimeter- Depew (NY)
Calibration Date:	On the day of Use
Instrument Settings:	Settings A, slow response

Baseline Area Noise Sample Results

Department	**Noise source**	**Sound levels** *(30-second samples)*	
		Leq (dB)	**LPeak (dB)**
Utility Plants	Boiler 1	81.8	95.3
	Boiler 2	82.6	95.8
	Transfer water pump	79.8	92.6
	Condensate pump	77.1	90.5
	Feed water pump	82.9	95.8
	Quinsv^{TM} compressor	92.3	104.3
	Reverse osmosis system	92.6	104.3
	Generator 1 east utility plant at start	88.0	104.7
	Generator 1 east utility plant at run	89.7	103.7
Ground Crew	Snow remover S 450 @ driver Seat	75.7	88.3
	Snow remover LS160 @ driver Seat	76.1	87.7
	Snow remover S 850 @ driver Seat	67.6	80.1
	Lawn mower	77.7	89.9
	Leaf blower backpack	92.6	104.7
	Leaf blower hand held	83.8	96.9
Utility Vehicle Users	Kubota utility vehicle (door open)	56.5	72.8
	Kubota utility vehicle (door closed)	67.2	75.9
	Kubota utility vehicle full power (uphill)	69.7	81.0
	Gators utility vehicle (door open)	78.8	94.4
	Gators utility vehicle (door closed)	71.1	113.8
	Gators utility vehicle full power at (uphill)	73.9	89.1
Comparative Medicine	Clean rack & tunnel washer	76.0	98.6
	Dirty rack & tunnel washer	75.5	96.1
	Non-human primates (Pig rooms)	82.3	101.2

- Equivalent continuous sound level (Leq) = Single decibel (dB) value of all fluctuating sound energies.
- Peak sound level (Lpeak) = Highest sound pressure

Baseline Personal Dosimetry results

Department	Run Time (hours)	NIOSH TWA (8) (dBA)	NIOSH Percent Dose (%)	OSHA PEL TWA (8) (dBA)	OSHA PEL % Dose
Utility Plants	8.02	79.5	28.4	72.3	8.6
	8.05	80.2	33.1	73.4	10.0
	8.00	80.1	32.5	74.2	11.2
	7.47	79.4	25.6	72.6	9
	7.33	**86.6**	**132.7**	84.3	45.5
	7.50	**86.8**	**135.7**	**85.1**	**50.7**
Ground Crew	7.63	**85.2**	**100**	83.7	42
	7.88	84.6	89.8	79.6	23.6
	7.65	**90.6**	**348.7**	81	28.8
	7.72	**85.0**	96.5	79.3	22.8
	7.70	**87.1**	**156.4**	84.4	46
	7.73	**85.7**	**113.6**	81.2	29.4
Utility Vehicle Users	7.51	**96.2**	**1249.6**	**87.5**	**71**
	7.43	80.9	36	74.8	12.2
	8.15	**85.2**	**106.7**	76.2	14.8
	8.38	77.5	18.5	66.9	4.1
	8.20	82.5	57.5	76.8	16.1
	8.20	78.9	25	71.4	10.3
Comparative Medicine	7.17	81.1	36.6	77.1	16.7
	7.45	77.6	16.8	70.7	6.9
	8.18	**85.1**	**104.7**	82.4	34.9
	7.70	74.4	8.3	66.5	3.9
	8.05	84.2	83.6	76.8	16.0
	7.67	80.5	33.9	74.9	12.4
Security Officers	7.55	72.9	5.8	63.0	2.4
	7.88	75.2	10.3	66.4	3.8
	8.05	70.8	3.8	60.7	1.7
	7.33	69.3	2.4	60.3	1.6
	7.90	65.3	1.0	50.3	0.4
	7.62	67.2	1.6	54.9	0.8

- NIOSH TWA = Eight-hour Time Weighted Average (TWA)based on the National Institute for Occupational Safety and Health (NIOSH) Recommendation Exposure Limit (REL)
- NIOSH % Dose = Percent dose based on NIOSH REL (85 dBA = 100% dose)
- OSHA PEL TWA = Eight-hour TWA based on the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL)
- OSHA PEL % dose = Percent dose based on OSHA PEL (90 dBA = 100% dose)