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Hearing Conservation in a Meat Processing Facility

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ABSTRACT

Introduction: The aim of this study was to evaluate personal noise exposures at a meat processing facility, and educate employees on the proper use of hearing protectors. **Materials and Methods:** We collected full-shift personal dosimetry on thirty-six production floor employees, one quality control employee, and four maintenance employees. These were compared to the National Institute for Occupational Safety and Health (NIOSH) and the Occupational Safety and Health Administration (OSHA) criteria. We also collected point source noise measurement at eight workstations from precook. We administered a questionnaire to assess production floor employees' hearing loss perception and non-occupational source of noise exposure. We also documented how employees inserted the earplug provided by the facility (Moldex SparkPlugs) following the required three steps of inserting an earplug: (1) roll the earplug; (2) pull the ear with opposite hand across the head; (3) insert the earplug. We provided employees with two earplugs (3M Ultra Fit, and E-A-R Classic) to evaluate their preference. We used Fisher exact test to evaluate the association between employees' questionnaire response and the way they insert earplugs, and employees' questionnaire response and their earplug preference. **Results:** Thirty-three (80.48%) of the measured personal noise level exceeded the NIOSH Recommended Exposure Limit, twenty-nine (70.73%) of these exceeded the OSHA Action Level and nine (21.95%) exceeded the OSHA Permissible Exposure Limit. The point source noise levels ranged from 81.5 dBA to 97.5 dBA using an A-weighted scale (dBA). Maximum measured sound level was 97.5 dBA and 96.1 (dBC). Loudest noise levels occurred between 2500 Hertz (Hz) – 4000 Hz at four workstations. Eight (12.90%) employees inserted earplugs correctly. Forty-two (56.76%) preferred the 3M Ultra Fit earplug over other types. Twelve (16.44%) reported they experience ringing in the ear, and of these eight reported

improvements in the ear over time. Most of the employees did not report difficulty in hearing. There was a significant association (p-value 0.02) between employees' use of hearing protection device (HPD) outside of work around loud noise and the way they inserted earplugs. Employees who used HPD outside of work around loud noise inserted earplug correctly as compared to those who did not use HPD outside of work around loud noise. There was no significant relationship between employees' questionnaire response and their earplug preference.

Conclusion: Production floor employees and maintenance employees are exposed to excessive loud noise level, and they are at risk of developing noise-induced hearing loss (NIHL). Employees that work over full shift at workstations with the loudest exposure between 2500 Hz - 4000 Hz are at risk of NIHL development. Implementation of engineering control may reduce loudest noise exposure that occurred at 2500 Hz - 4000 Hz. Adequate training on the proper use of earplugs, and provision of varieties of earplug may increase employees' compliance with the proper use of hearing protectors.

Impact of the Project: This project will enable us to do the following: (1) identify employees who should not be enrolled in a hearing conservation program (HCP); (2) monitor noise levels at different frequencies related to NIHL development; (3) educate employees on the proper use of earplug; (4) determine employees' preference for earplug types. This will assist the facility's management to select suitable earplugs for purchase and to evaluate the effectiveness of the facility's hearing conservation program per the hearing conservation amendment. Also, it will help the management to implement the best control measure (engineering control) where needed. This project will serve as a baseline for the facility's HCP management.

INTRODUCTION

Noise is one of the most prevalent of all occupational hazards with the exposure known to be a serious concern since the beginning of the industrial revolution (Achutan, 2014; Suter, 2017). Noise exposure is a global health occupational problem (Kanji et al., 2018). The estimated health impact of noise exposure is 4 million disability-adjusted life-years (DALYs); of this 16% to 24% is work-related (Nelson et al., 2005). Noise exposure in occupational settings leads to noise-induced hearing loss (NIHL). This condition is preventable but irreversible. It can also influence the function of other body systems causing vibroacoustic disease (VAD) (Branco & Alves-Pereira, 2004); major depressive disorder (MDD) (Oenning et al. 2018); and elevated blood pressure, stress, annoyance, and tinnitus (Nelson et al., 2005). According to Tomei et al. (2010), there is a significant association between NIHL and hypertension.

NIHL is the most common sensorineural hearing loss. It is also the most common self-reported occupational illness after presbycusis (Rabinowitz, 2000). It is a preventable hearing loss that is accompanied by tinnitus (Dobie & Kopke, 2014; Mazurek et al., 2010; Kanji et al., 2018; Savastano, 2008). For people with NIHL, hearing levels at the high-frequencies (3 kilohertz [kHz] - 6 kHz) are more likely to be impaired than at the low-frequencies (250 hertz [Hz] – 2 kHz) (Dobie & Kopke, 2014). According to Feder et al. (2016), 11.2 million workers (42%) were exposed to hazardous noise in Canada. Feder et al. (2016), elucidated that 10years or more workplace hazardous noise exposure will double the odds of their study participants of having hearing loss.

In the United States, an estimated 30 million American workers are exposed to hazardous noise in their work environment (Tantranont & Codchanak, 2017), with an additional 9 million workers at potential risk of developing hearing loss from non-noise agents (Hutchison & Kirchner, 2014). The U.S. Bureau of Labor Statistics (BLS) reported that hearing loss accounted for approximately 12% of the 155,000 recorded occupational injuries and illnesses in 2010. It is one of the five categories of occupational illnesses which has declined from 3.2 to 2.2 cases per 10,000 full-time workers between 2004 and 2010 respectively. Primary metal manufacturing, air transportation, and food manufacturing industries are the top industries where the highest hearing loss rates were reported. In 2010, food manufacturing industry has the third highest hearing loss rate at the three-digit North American Industry Classification System (NAICS) level (BLS, 2012). The industry will continue to be very loud, relatively due to the substitution of manual processes with automated (BLS, 2012). Therefore, the need to reduce or eliminate hazardous noise exposure in the workplace is essential.

Following the Occupational Safety and Health Administration (OSHA) noise standard 29 Code of Federal Regulations 1910.95 (29 CFR 1910.95), employees with a noise exposure level at or above 85 dB(A) over an 8-hour time-weighted average (TWA) must be enrolled in a hearing conservation program (HCP). The HCP is designed to prevent NIHL (Hutchison & Kirchner, 2014; Schaible & Swisher, 2014). HCP components include noise measurement, noise control, hearing protection, audiometric monitoring, worker training and motivation, recordkeeping, and program evaluation. An audiometric evaluation is a major way to ascertain the prevention of occupational hearing loss (NIOSH, 1998) by determining employees' hearing level (HL).

Although most industries abide by OSHA's noise standard by enrolling employees' in HCP, they may not follow the components of the program accordingly. The main objectives of this study were to assess noise exposures at a meat processing facility, educate and train employees on the proper use of hearing protection devices.

METHODS

Description of Study Site

The study site was a meat processing facility that produces bacon, and pizza toppings as final consumable products for customers. The facility is divided into nine departments with approximately 900 workers. The departments are: human resources, maintenance, administration, food safety and quality, occupational health, safety, production, logistic, and security. This facility operates 24 hours daily with three shifts. Meat is processed during the first two shifts. Employees are entitled to two breaks: the first break is for 10 minutes and the second break is for 30 minutes. The facility provides personal protective equipment (PPE) for the production, safety, maintenance, food safety and quality department employees.

Production department

This department is where the facility receives fresh and frozen pork bellies from vendors. The bellies are scanned into the computer system for audit purpose. Employees working on the production floor are required to wear the following PPE: apron (frock), hearing protection device (earplug, earmuff), hand glove, hard hat, safety glass, and boot. The production department is mainly divided into three work areas: (1) curing; (2) retail; and (3) precook. Each work area is further divided into multiple sections by job tasks.

Curing

The curing work area is where the facility receives the pork bellies from the vendors. The work area has four operation line. The bellies are transported by a tow motor driver to a thaw room for storage. Frozen bellies are thawed by the use of water for about 3-4 days. Bellies (thawed frozen bellies, and fresh bellies) are transported by a forklift driver to a curing dumper where the meat processing begins. The weight of the bellies is between 8 and 22 pounds. At each operation line, meat processing undergoes the same procedure. A line feeder operator drags the bellies to the belly dragger operator with a hook called long hook. The belly dragger makes use of a hook called belly hook to move the bellies to a conveyor belt. The conveyor belt is an automated machine that moves the bellies to the pickle injection room. The pickle injection room is where bellies are injected with a pickle flavored liquid. This liquid adds flavor to the bellies. After injecting the bellies, the conveyor belt moves the bellies to the belly hanger. This is a manual process where employee hook pork bellies with a metal rod called comb. The hooked combed bellies are hanged on a moveable metal rack (metal rack with wheel) called tree. About 75-90 pork bellies are hung on a tree. The bellies are wheeled by the tree puller to the smokehouse. At the smokehouse, bellies are partially cooked with smoke. Based on customer request, bellies are either cooked with natural smoke or liquid smoke. For the natural smoke, sawdust is used for cooking. Irrespective of the smoke type, bellies are cooked for 6 hours and chilled for 4 hours. The chilled bellies are stored under a room temperature of 18-19 ^{o}F for cooling. The bellies are then dragged by an employee (cooler tree puller) to a pressing machine at the retail work area.

The used trees are washed by tree washers after off-loading the bellies at the retail work area, and then put back into service.

Retail

The retail work area is where the ready to cook bacon is processed. Ready to cook bacon are traditional bacon product that needs to be cooked conventionally by the consumer after purchase. The work area is divided into the following sections: (1) old retail 1, (2) old retail 2, and (3) new retail. Bacon process undergoes the same process at each section but the sections differ by design. The old retail 1 has eight operation lines, the old retail 2 has three operation lines, and the new retail has four operation lines. At these work area, the partially cooked bacon undergo the following processes: (1) pressing; (2) slicing; (3) arranging and packaging. Three press operators work at the pressing workstation. One press operator removes bellies from the tree, the second press operator feeds the bellies into the pressing machine, and the third press operator presses the bellies with the pressing machine. The purpose of pressing the bellies is to make it have a regular and definite shape. The pressed bellies are either manually inserted by a line feeder operator into a machine that slices the bellies or are transported by a forklift driver to the precook work area. The slicing machine is operated manually by an employee called the slicer. The sliced bellies are conveyed to either a v-pack operator, tux operator or a multivac operator for packaging depending on customer's request. The v-pack operator is an employee in charge of paper bag packaging. Tux packaging is also a paper bag packaging. The tux operator is an employee in charge of the tux packaging. The multivac is a plastic bag packaging that is managed by a multivac operator.

Precook

The precook work area is where the ready to eat bacon is processed. Ready to eat bacon is microwaveable bacon and pizza toppings. The work area is divided into four main sections: grote (slicing); microwave (cooking); packaging, and arranging (multivac/tux). The partially cooked and pressed bellies received from the retail work area are then sliced. An employee (grote operator) slices the bacon through a machine called grote which is then sent to an industrial microwave that cooks the bacon. The microwave is operated a microwave operator. The ready to eat bacon is then packaged and arranged by a multivac operator or a tux operator depending on the customer's request. The multivac packaging and the tux packaging is the same as that of the retail work area. A multivac operator and a tux operator do the packaging. A box packer places these packages in boxes; a forklift driver moves these boxes to the warehouse for eventual distribution.

Food safety and quality department

Employees working in the food safety and quality department oversee the quality of the plant's final consumable products (bacon, pizza toppings). They determine if the quality is met per requirements. A quality control employee (QC) collects samples from the production floor, and then inspect them in a dedicated laboratory for analysis.

Maintenance department

The maintenance department employees ensure that all machines on the production floor are running properly. Employees in this department have different job titles per their work sections. The wastewater operators are in charge of wastewater treatment at the facility. They control waste treatment equipment and ensure that the release of residual water to the environment is safe. A boiler operator maintains, repairs, and ensure that the plant's boiler is in proper working order. The refrigerator employees are those that are in charge of the facility's refrigeration system. A forklift driver moves about equipment when needed on the production floor. The pump technician maintains, repairs and ensure pumps are in working order. An electrical technician installs, inspect electrical components, and control lighting system at the facility. The pump technician and electrical technicians goes around the production floor to ensure that the pump and the lighting system are in working condition.

The study was approved by the University of Nebraska Medical Center Institutional Research Board.

Noise Measurement

Personal Dosimetry

We used Spark 706 noise dosimeters (Larson Davis, Depew, NY) to collect full-shift noise dosimetry data. The dosimeters were calibrated daily before use. They were set to collect data per the OSHA and NIOSH criteria [Table 1].The dosimeter was placed in the participant's pocket and the microphone was clipped to their frock on the shoulder close to the ear. The collected noise measurements were downloaded to a laboratory computer for interpretation using the Blaze software (Larson Davis, Depew, NY). Forty-one employees participated in the noise dosimetry. We collected 36 samples from the production floor, one sample from the food safety and quality department, and four samples from the maintenance department. The production floor samples were taken at the following work areas: curing (n=7), precook (n=18), and retail (n=11). The retail samples were further divided into new retail (n=4), and old retail (n=7).

Table 1: Dosimeter Settings

Parameters	**OSHA PEL**	**NIOSH REL**	**OSHA AL**
Response	Slow	Slow	Slow
Exchange rate	5	3	5
Threshold	80	80	80
Criterion level	90	85	85
Upper limit	114	114	114

Point Source Noise Sample

The point source noise measurements were taken with a SoundTrack LxT® analyzer model (Larson Davis, Depew, NY), with no microphone correction. The analyzer allows for the analysis of noise into its spectral components in a real-time mode, with a linear integration method. In the region of concern, the microphone allows for the analysis of sounds at a frequency response that ranged from 8.0 Hertz (Hz) to 16 kiloHz (kHz). The analyzer was integrated for 1 minute with one-third octave bands that consist of center frequencies from 6.3 Hz to 20 kHz. Sound levels at different workstations at precook were captured. The analyzer microphone was pointed close to the machine noise source. The integrated sounds were stored for later analysis. The collected sound levels were downloaded using the Blaze software (Larson Davis, Depew, NY).

Employee Outreach

The purpose of the employee outreach was to assess employees' hearing loss perception and document their non-occupational source of noise exposures. In addition, we wanted to evaluate their ability to insert earplugs, and also determine if the ear plugs [Moldex SparkPlugs Metal Detectable (Moldex-Metric, Inc, Culver City, CA)] provided by the company is the most comfortable for the employees. We asked shift supervisors to send us small groups of production floor employees for this study. Seventy-one production floor employees, and three food safety and quality employees completed a short questionnaire, sixty-two of these inserted the earplug provided by the company, and all employees' (n=74) inserted two additional earplugs provided by the researchers to evaluate earplug preference. Fifteen of the employees that completed the questionnaire were earmuff users, but three of these inserted the earplug provided by the company.

Questionnaire

The questionnaire was scaled using a three-point and a five-point Likert-type scale. The questionnaire is provided in the Appendix.

Evaluating employee knowledge on inserting earplugs

We created a checklist to evaluate how employees were inserting the earplugs provided by the company. The checklist was divided into three steps: (1) roll the earplug (prepare the earplug); (2) pull the ear with opposite hand across the head; and (3) insert the earplug. We observed employees that participated in the questionnaire section, check their earplug inserting steps for the Moldex SparkPlugs earplug. In situations where employees brought in a different earplug from the Moldex SparkPlugs, we allowed them to wear these. Immediate feedback was given to employees about the correct insert of earplugs. We evaluated the association between employees' questionnaire response and the way they insert earplugs using fisher's exact test.

Evaluating employee preference for different earplugs

In addition to the company-supplied earplug, we provided employees with two additional earplugs: [3M Ultra fit, and E-A-R Classic (3M Company, St. Paul, MN)]. Employees were trained in small groups not exceeding five, on how to insert these earplugs. We did not account for the influence of peer group effect on employees' choice for earplug selection. We evaluated employees' questionnaire response and their earplug preference using fisher's exact test.

Statistical Analysis

SAS version 9.4 (SAS Institute, Cary, NC) was used for analyses. We used descriptive statistics to summarize employees' hearing loss perception and their non-occupational source of exposures. Fisher's exact test was done to assess the association between the following: (1) employees' hearing loss perception with their non-occupational source of noise exposures, and the way they inserted earplugs; (2) employees' hearing loss perception with their non-occupational source of noise exposures, and their earplug preference. A p-value < 0.05 was considered statistically significant.

RESULTS

Noise Measurement

Personal Dosimetry

The measured personal dosimetry were evaluated and compared to the following three noise criteria: (1) the NIOSH REL of 85 dBA over 8 hours TWA using a 3 dB exchange rate; (2) the OSHA PEL of 90 dBA over 8 hours TWA using a 5 dB exchange rate; and (3) the OSHA AL of 85 dBA using a 5 dB exchange rate. Each of these standards is equivalent to 100% noise dose. Table 2 summarizes the personal dosimetry measurements in TWA and percent dose.

Table 2: Range of Personal Noise Measure from Tyson Foods Employees

Work Area	Job Title	Shift	Position	OSHA PEL [TWA] (Dose %)	OSHA AL [TWA] (Dose %)	NIOSH REL [TWA] (Dose %)
Curing	Smoke house operator	1	N/A	86.6 (64.8)	86.9 (129.5)	92.3 (536.9)
	Smoke house operator	2	N/A	89 (89.5)	89 (173)	93.9 (719.5)
	Tree washer	1	N/A	86.5 (61.5)	86.5 (123.1)	87.4 (173.9)
	Tree washer	2	N/A	87.2 (67.7)	87.2 (135.5)	88.4 (220.2)
	Tow motor operator	1	N/A	86.2 (60.6)	86.4 (121.2)	86.9 (154.9)
	Line feeder	1	N/A	84.7 (47.7)	84.7 (95.4)**	85.7 (117.8)
	Pump technician	1	N/A	85.2 (51.5)	85.2 (103.1)	88 (199.1)
Retail						
Old Retail 1	Line feeder	2	N/A	90 (100)*	90 (199.9)	90.9 (387.8)
	Press operator	2	N/A	89.1 (88.9)	89.1 (176.1)	90.1 (1031.5)
Old Retail 2	Slicer	2	Line 1	87.7 (72.8)	87.7 (145.6)	88.4 (220.7)
	Tux operator	2	Line	85.2 (51.20	85.2 (102.4)	87 (146.8)
	Press operator	2	17/18	88 (75.7)	88 (151.5)	89.2 (260.8)
	Box packer	2	Line 17	85.6 (54.2)	85.2 (108.3)	86.6 (461.5)
			Line 18			
New Retail	Scaler	2		85.6 (54.2)	85.6 (108.3)	86.6 (461.5)
	Multivac operator	2	Line 23	86.6 (62.1)	86.6 (124.3)	87.7 (187)
	Arranger	2	N/A	88 (75.7)	88 (151.5)	89.2 (260.8)
			Line 24			
Precook	Grote operator	1	Line 1	90.5 (106.6)*	90.5 (213.2)	91.5 (445.6)
	Grote operator	1	Line 8	92.3 (136.9)*	92.3 (273.8)	92.6 (569.3)
	Grote operator	2	Line 5	82.2 (34.0)	82.2 (68)**	83.24 (66.65)***
	Grote operator	2	Line 123	71.4 (7.6)	71.4 (15.3)**	77.6 (18.4)***
	Microwave operator	1	Line 1	86.2 (59.1)	86.2 (118.2)	87.5 (177.9)
	Microwave operator	1	Line 5	90.6 (107.9*	90.6 (187)	91.3 (430)
	Microwave operator	2	Line 6	89.3 (91.1)	89.3 (182.3)	90.2 (330.6)
	Microwave operator	2	Line 7	90.97 (114.35)*	90.97 (228.7)	92.08 (511.03)
	Multivac operator	1	Line 2	92.8 (147.4)*	92.8 (294.8)	93.1 (724.4)
	Multivac operator	1	Line 4	93.1 (154.2)*	93.1 (308.3)	94.3 (860.6)
	Multvac operator	1	Line 5	88.8 (85.2)	88.8 (170.5)	91.2 (416.3)
	Multivac operator	1	Line 7	94.4 (183.6)*	94.4 (367.2)	95.3 (1073.9)
	Forklift driver	1	N/A	89.1 (88.8)	89.1 (177.6)	91.7 (464.4)

	Tux operator	1	Line 4	84.3 (45.2)	84.3 (90.3)**	85.1 (102.9)
	Pack off general	1	N/A	82.4 (34.9)	82.4 (69.9)**	84.4. (87.7)***
	Grote operator	1	N/A	90.8 (126)*	90.8 (252)	91.8 (538.1)
	Quality control (QC)	2	N/A	79.4 (23)	79.4 (46)**	83.9 (77.1)***
	Electrical technician	2	N/A	73 (9.5)	73 (19.1)**	83.1 (64.4)***
Maintenance	Forklift driver	1	N/A	84.5 (46.8)	84.5 (93.6)**	88.7 (232.7)
	Waste water operator	1	N/A	85.1 (50.5)	85.1 (101.1)	89.5 (283.4)
	Boiler operator	1	N/A	87.9 (74.3)	87.9 (148.7)	91 (394)
	Refrigerator	1	N/A	80.9 (28.4)	80.9 (56.7)**	86.2 (130.8)

The percent dose is the amount of noise accumulated over the full shift, with 100% representing the maximum allowable daily noise.
*OSHA PEL reached or exceeded once
** OSHA AL not reached
***NIOSH REL not reached

Of the forty-one measurements, three were excluded due to instrument failure or employees not wanting to continue the study. Thirty-three (86.84%) noise levels exceeded the NIOSH REL. Of these, twenty-nine (76.31%) also exceeded the OSHA AL and nine (23.68%) exceeded the OSHA PEL. Noise measures from the curing work area exceeded the NIOSH REL and OSHA AL except for the line feeder operator with a noise level of 84.7 dBA. None of the measured noise levels at the retail work area was below either the NIOSH REL or the OSHA AL. At the precook work area, multivac operators and microwave operators noise levels exceeded the evaluation criteria except for a multivac operator and two microwave operators whose noise levels were below the OSHA PEL of 90 dBA. The Forklift driver's noise level exceeded both the OSHA AL and NIOSH REL. Of the five grote operators we sampled, the noise levels for the two operators who worked during the second shift (Figure 1) was below the NIOSH REL. Their noise levels were 77.6 dBA and 83.24 dBA. These exposures are lower than the three operators who worked during the first shift (Figure 2). The black boxes indicates the periods when employees were on break.

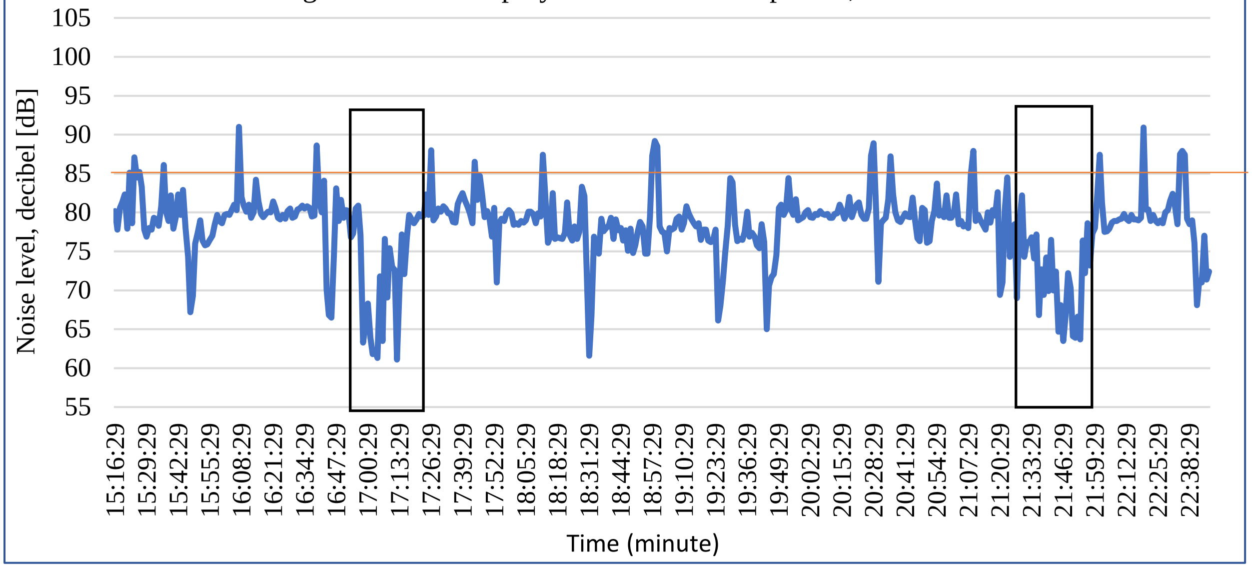


Figure 1: Grote employee real-time noise profile, 2nd Shift

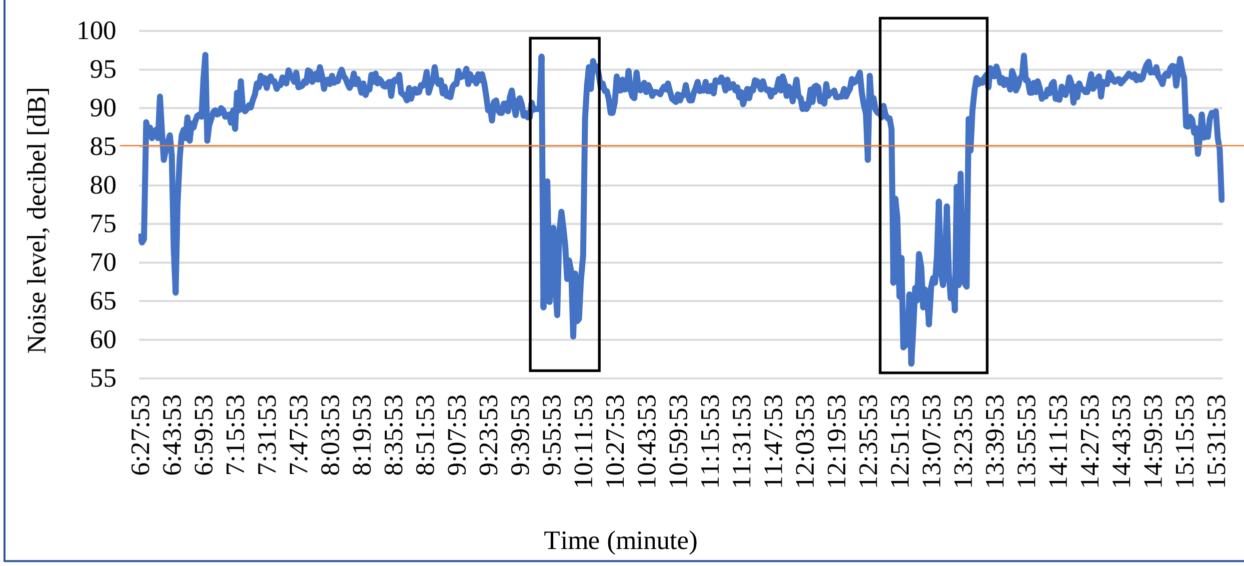


Figure 2: Grote employee real-time noise profile, 1st Shift

Noise levels for the pack off general employee, the quality control (QC) employee, and the electrical technician were below the OSHA AL and the NIOSH REL. The tux operator measured noise level exceeded the NIOSH REL but was below the OSHA AL. The measured noise level was 85.1 dBA. At the maintenance department, measured noise levels exceeded the NIOSH REL of 85 dBA but below the OSHA PEL of 90 dBA. Two employees' noise levels were below the OSHA AL of 85 dBA.

Point Source Noise Sample

The sound level meter collects noise levels in decibels using an A-weighted scale (dBA) and a C-weighted scale (dBC). Noise levels ranged from 81.5 dBA – 97.5 dBA (Table 3).

Table 3: Point Source Noise Levels at different work areas on the Production Floor

Work area	Machine (Location)	Noise Level [dBA]	Noise Level [dBC]
Precook	Pizza topping taping	85.3	86.9
Precook	Tux operator	81.5	84.0
Precook	(Line 7,8)	96.7	95.9
Precook	(Line 7,8)	91.8	91.1
Precook	(Line 7,8)	90.4	90.2
Precook	(Line 4)	97.5	96.1
Precook	(Line 1-3)	90.1	92.5
Precook	(near multivac)	87.2	91.0

The highest sound level measurement (97.5 dBA) was taken at line 4. The loudest exposures occurred between 2500 Hz – 4000 Hz frequency. These were measured at four machine locations. Three of these were measured at line 7&8, and one was from line 4 (4000 Hz) (figure 3). Of the three loudest measured sound level at line 7&8, two occurred at 3150 Hz frequency (figure 4), and one occurred at 2500 Hz. The measured maximum sound levels was 97.5 dBA and 96.1 dBC respectively.

Figure 3: Spectral Noise Data at line 4

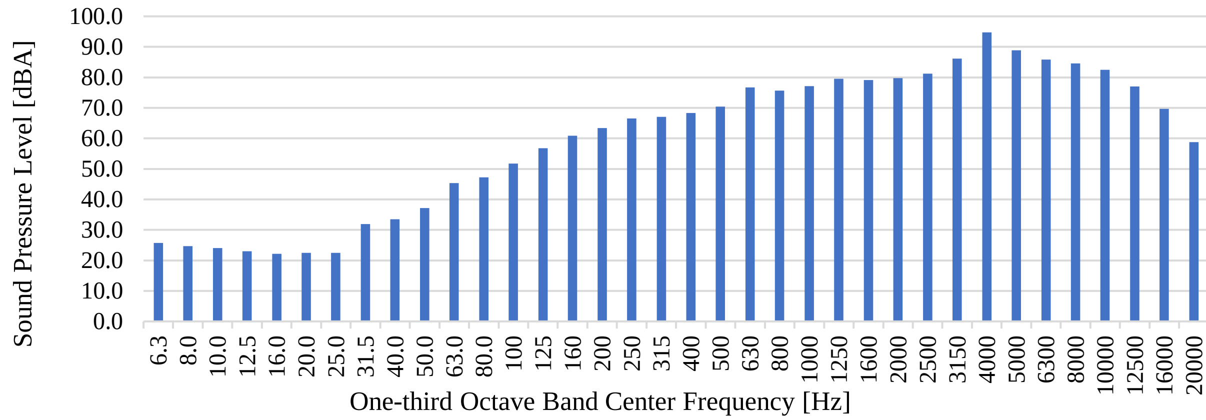
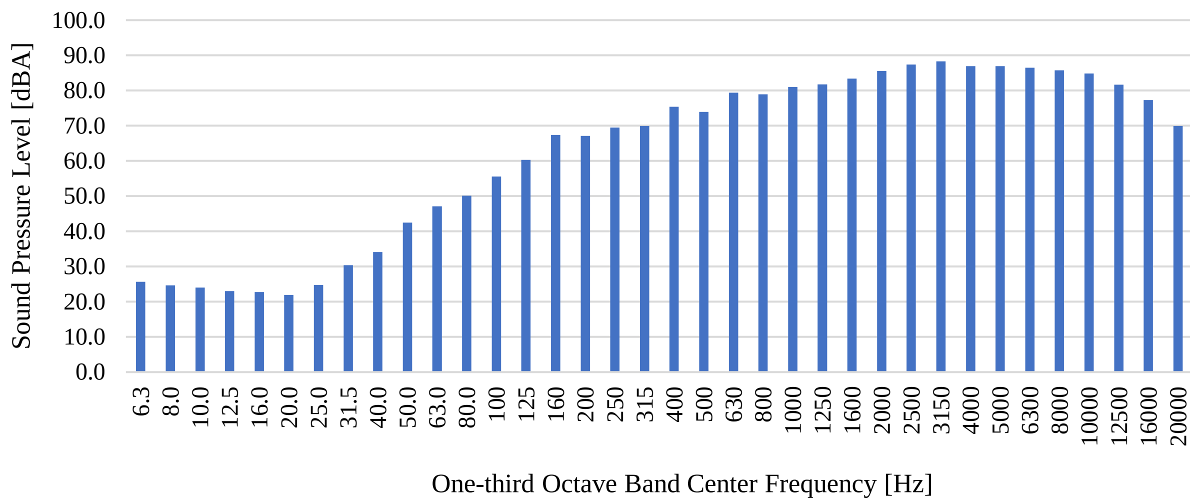


Figure 4: Spectral Noise Data at line 7,8



Employee Outreach

Questionnaire

Of the seventy-four study participants who completed the questionnaire, twenty-nine (41.43%) were female and forty-one (58.57%) were male. Fifty (67.56%) used Moldex SparkPlugs earplugs; fifteen (20.27%) were earmuff users; while nine (2.16%) were “Other” earplug users. These premold earplugs were not provided by the facility, but employees were allowed to it. Employees’ age ranged from 22 years to 65 years with mean age of 40.27. Sixty-one participants

(82.43%) reported they work ≥ 48 hours weekly. Forty-eight (64.86%) participants have worked for more than five years at the facility. Twenty (27.02%) reported they participate in the following activities: rock band/ loud music (n=9), hunting (n=1), lawn mowing grasses (n=9), trap shooting/firing range (n=1). Of these only one reported the use of earplugs when participating in trap shooting/firing range activity. Twelve (16.44%) reported they experience ringing in the ear. Of these, eight reported improvement in the ear over time. Five (6.85%) do not know if they experience ringing in the ear. Three (4.17%) employees reported they use earplugs outside the work environment; 1.39% (n=1) do not know if noise is too loud outside of work when they are around loud noise. Over 85% employees reported they never had difficulty in hearing.

Evaluating employee knowledge on inserting earplugs

Sixty-two employees participated in how to insert the Moldex SparkPlugs earplug. Of these three were earmuff users, and two of these were dual protection (earmuff and earplug) users. Twelve participants were excluded because they were earmuff users, and decided not to participate. Following the required three steps of inserting earplug with the Moldex SparkPlugs, and others, twenty-four participants rolled the earplug; eleven pulled their ear with the opposite hand across the head; and twenty-three inserted the earplug. Of these, only nine inserted the earplug correctly following the steps [Table 4]. Six (75%) participants of aged ≤ 34 years inserted earplug correctly. Participants (n=7) with more than 5 years of working experience at the facility inserted the earplug correctly.

Table 4: Employees earplug inserting steps result

		Earplug inserting steps			Evaluation	
Earplug name	**No. of employees**	**Roll**	**Pull**	**Insert**	**Correct**	**Incorrect**
Moldex SparkPlugs	53	24	8	16	6	47
Others (premold)	9	0	3	7	3	6

Of the participants (n=12) that experience ringing in the ear, only two inserted the earplug correctly. Two of the three participants that use hearing protection outside of work environment inserted the earplug correctly. There was a significant association between employees' use of HPD outside of work whenever they are around loud noise and the way they inserted earplugs [Table 5].

Table 5: Association between employees' questionnaire response and how they insert earplug

	Earplug fit		
Variable	Incorrect fit n (%)	Correct fit n (%)	P-value
Gender			
Female	23(46.00)	2 (22.22)	
Male	27 (54.0)	7 (77.78)	0.28
Age group, year			
≤ 34	19 (37.25)	6 (66.67)	
35-54	27 (52.94)	3 (33.33)	
≥ 55	5 (9.80)	0 (0.0)	0.33
Work experience at plant, years			
<1	9 (16.67)	1 (11.11)	
1-5	14 (25.93)	1 (11.11)	
6-10	18 (33.33)	6 (66.67)	
>10	13 (24.07)	1 (11.11)	0.40
Experience ringing in your ear			
Yes	10 (18.87)	2 (22.22)	
No	41 (77.36)	7 (77.78)	
I do not know	2 (3.77)	0 (0.00)	1.00
Use HPD outside work			
Yes	0 (0.00)	2 (22.22)	
No	51 (98.08)	7 (75.00)	
I do not know if noise is too loud	1 (1.92)	0 (0.00)	0.02**

*Note: The total observation for each variable should be equal to sixty-two (n=62), where the observation is not equivalent to 62, responses were missing

**p < 0.05

Evaluating employee preference for different earplugs

All the employees (n=74) participated in evaluating their preference for earplugs. Forty-two (56.76%) preferred the 3M Ultra Fit earplug, [n=26 (35.14%)] preferred Moldex SparkPlugs earplug, and [n=6 (8.11%)] preferred the E-A-R Classic earplug. Of those that preferred the 3M Ultra Fit earplug, nine represented the others (premold) earplug users. Although there was no significant association between employees' questionnaire response and their earplug preference, employees that preferred the Moldex SparkPlugs earplug: 42.31% (n=11) were of aged ≤ 34 years; 50% (n=13) were of aged 35-54 years; 7.67 (n=2) were of aged ≥ 55 years. Four (15.38%) employees with less than one year; 26.92% (n=7) with 1-5 years; 30.77% (n=8) with 6-10 years; and 26.92% (n=7) with ≥ 10 years working experience at the plant preferred the Moldex SparkPlugs earplug. Two (7.69%) of the twelve employees that experience ringing in the ear; four (15.34%) of the five employees that do not know if they experience ringing in the ear choose the Moldex SparkPlugs earplug over the provided earplugs. Of the three employees that use HPD outside of work when they are around loud noise, 8% (n=2) preferred the Moldex SparkPlugs; 2.44% (n=1) preferred the 3M Ultra Fit earplug.

For the 3M Ultra Fit earplug preference, 24.39% (n=10) of the twelve employees that experience ringing in the ear; 2.44% (n=1) of the five employees that do not know if they experience ringing in the ear preferred the 3M Ultra Fit earplug. Of the forty-two employees that preferred the 3M Ultra Fit earplug, three did not report their age; 33.33% (n=13) were of aged ≤ 34 years; 51.28% (n=20) were of aged 35-54 years; 15.38% (n=6) were of aged ≥ 55 years. Four (66.67%) of aged 35-54 years; and two (33.33%) of aged ≤ 34 years preferred the E-A-R Classic earplug. Six (14.29%) employees with less than one year; seven (16.67%) with 1-5 years; seventeen (40.48%) with 6-10 years; and twelve (28.57%) with ≥ 10 years working experience at the plant preferred the 3M Ultra Fit earplug. Four (66.65%) employees with 6-10 years; and two (33.33%) with 1-5 years working experience at the plant preferred the E-A-R Classic earplug.

DISCUSSION

Occupational noise exposure has been a concern globally due to the health problems. Noise-induced hearing loss (NIHL) is one of the health problems. The main result of this study is that employees working on the production floor at a meat processing facility are mostly exposed to hazardous noise at work that ranged from 83.24 dBA to 95.3 dBA per NIOSH REL of 85 dBA, and the substitution of manual process with automated is the relative reason (BLS 2010). Over 76.31% employees were exposed to hazardous noise that ranged from 101.1% to 367.2% per the OSHA AL noise dose. Grote operators' real-time noise profile at different shifts (1st and 2nd shift) was surprising. The reason for the difference in employees' real-time noise profile could be that: (1) more products were made during the 1st shift; (2) inadequate cleaning of the grote machine at the end of the 1st shift prior to the beginning of 2nd shift might have underestimated the 2nd shift employees noise levels. Maintenance department employees' noise levels were not consistent over full shift with some exposure exceeding both the NIOSH REL and the OSHA AL, while others were below the OSHA AL. Maintenance department employees perform a variety of tasks with varying durations. Therefore, it is possible that their exposures can also vary. For this reason, it is prudent to keep these employees in a hearing conservation program even if some of their exposures did not exceed the OSHA AL. We were surprised that the QC and electrical technician's noise levels were below the NIOSH REL. The reason for these could be because the employees did not work on machines throughout their full shift and they were floating employees (did not spend their 8 hours full shift at precook). Due to our insufficient noise data for the QC employee; the electrical technician; and the pack off general employee, we were unable to conclude if they needed to be enrolled in an HCP. We recommend additional sampling to evaluate the employees' exposure levels. Also, the measured noise levels for the QC employee, and the electrical technician may not be generalizable at the facility because the samples were taken at precook work area only.

A-weighted noise levels (dBA) approximates the sensory response of the human ear to sound frequencies near the hearing threshold (20 Hz-20 kHz). Employees working around machines with exceeded dBA noise levels are at risk of developing NIHL if they work on such machine over full shift. We were not surprised with the loudest exposures at line 4 that occurred at 4000 Hz frequency because the highest measured sound level of 97.5 dBA over the 1minute sampling period was from the line. The difference in the measured sound levels at line 7&8 were surprising because the position and time at which samples were taken affected the measurement. The highest sound levels measurement [96.7 dBA, and 91.8 dBA] at line 7&8 were taken near the end of the lines, and a squealing sound was noticed during the first measurement which was reduced during the second measurement. The squealing sound might have influenced the increase on the first measurement. The measured sound level of 90.4 dBA at line 7&8 was taken at the beginning of the lines. The implementation of an engineering control may be helpful to reduce the measured loudest exposure that occurred between 2500 Hz – 4000 Hz frequencies. The need for an engineering control on those machines is because these frequencies (2500 Hz – 4000 Hz) are associated with NIHL that usually occur between 2000 Hz – 6000 Hz.

The use of personal protective equipment (PPE) is known to be a control measure after engineering and/ or administrative control has been implemented. The result from this study illustrated that 87.10% employees have not been inserting earplug correctly. These employees might have been under-protected over the years of their employment and may be at risk of NIHL development. Employees improper inserting of earplugs could be due to inadequate training on the proper way of inserting earplugs, inadequate emphasis during training on the health benefit of using HPD around loud noise, or hindrance from other PPE use. The use of other personal protective equipment (hard hat) prior to inserting earplug was observed to be a hindrance following the proper steps of inserting earplugs. This is because pulling of the ear with opposite hand across the head when employee's hard hat was on the head made it difficult for their hand to reach the ear. Although, hygiene was not the main purpose of observing employees earplug inserting steps in this study, proper hygiene of earplugs is encouraged to avoid ear infections when trying to prevent NIHL development. We observed that some employees tried rolling earplug with their used hand gloves.

Communication was the greatest challenge we had in training employees. There were five languages (like Nepali, Karen, Spanish, Burmese, and Karenni) and thirty-two dialects spoken at the facility, and a majority of the employees did not speak English. We requested interpreters at the plant for employees that did not speak English to achieve our goal. We trained employees on the proper steps of inserting earplugs, and educated them on the health benefit of using earplug around loud noise but human behavior is a big factor that cannot be ruled out completely. Lusk et al. (1997), stated that interpersonal influence was the strongest predictor of HPD use among construction workers (i.e. how much workers believe others use HPDs when exposed to noise, mostly their supervisors and coworkers with whom employee spend the most time). Also, McCullagh et al. (2002) discovered that interpersonal support was a significant predictor of HPD use among farmers. An employee complained of poor fitting of the earplug in the left ear, we observed the ear and discovered the earplug may not be the best HPD for such employee due to an unnoticed slight deformation of the left ear. This employee followed the proper steps of inserting earplug correctly, with the other earplug type. Proper ear examination of the employee by an audiologist was encouraged. Two employees mentioned they use dual protection (earmuff and earplug). This is not required per either the NIOSH REL or the OSHA AL based on the measured personal noise level we took. The highest personal noise level was 94.4 dBA for OSHA AL of 85 dBA, and 95.3 dBA for NIOSH REL of 85 dBA. The earplug provided by the facility had an NRR of 33 dBA which provides an estimate of 13 dBA noise reduction per the OSHA method for derating HPDs (Schulz T & Madison T, 2014). Using this method, the employee with the highest measured noise level of 94.4 dBA would have an estimated noise exposure of 81.4 dBA. Therefore, this employee would be overprotected from noise exposure. Over protection can be hazardous because employees may not hear warning signals designed to keep them safe (Schulz T & Madison T, 2014).

A majority of the study participants preferred another earplug to the one provided by the company. However, the earplug preference result showed that 56.76% preferred the 3M Ultra Fit over the E-A-R Classic and the Moldex SparkPlugs earplug. Peer group may have influenced some employees' decision on selecting earplug of their choice because we observed a group of employees selected a type of earplug based on what coworker choose. We enlightened them on selecting what they were most comfortable using and not what coworker choose but prompt and adequate training may help employees understand and practice the proper steps of inserting the facility's provided earplug because some employees mentioned that the Moldex SparkPlugs earplug was easier to roll (soft texture). The reported highest percentage (56.76%) for 3M Ultra Fit earplug could be because the earplug was the no-roll type. Employees stated their reasons for choosing this earplug over the other types. Most employees mentioned that the 3M Ultra Fit earplug was easier and faster to insert since they do not have enough time to roll earplug. For employees that selected E-A-R Classic earplug over the other two, they stated that the earplug covered the ear canal completely. Some employees mentioned that premold earplugs hurt after few hours. This could serve as a guide for the facility's management in purchasing and selecting varieties of earplug for employees. Madison & Schulz, 2014, stated that offering of earplug varieties and fit testing can increase employees hearing protection compliance and reduce work-related NIHL incidence.

Employees' hearing loss perception and non-occupational source of noise exposures response did not have an effect on their preference for earplug type. Also, employees' hearing loss perception and non-occupational source of noise exposures did not have an effect on the way they inserted earplugs except for those who use hearing protection (earplugs) outside work when they are around loud noise. We observed that of the six employees that inserted the Moldex SparkPlug earplugs correctly, five employees aged ≤ 54 years, with working experience more than 5 years at the facility, inserted it correctly. Age group may have an influence on the way employee inserted earplugs, or employees aged less than 55 years understand the importance of protecting their hearing. Also, these employees could have had several trainings on the proper way of inserting earplug. We were not surprised that the use of hearing protection outside of work was significantly associated with the way employees' inserted earplugs. This is because we postulated that continual use of earplug becomes a habit that increases the chances of inserting earplug correctly. Most of the employees that experienced ringing in the ear preferred the 3M Ultra Fit earplug over the other types.

The results from this study may not be generalizable as the study was conducted on one meat processing facility.

Strengths

We took convenient personal noise dosimetry samples across the production floor at different work areas, which allowed us to provide personal noise data for the facility We were able to estimate the production floor; food safety and quality control employees; and the maintenance employees' occupational noise exposure level. We were able to identify workstations with loudest sound level exposure at frequencies related to NIHL development. We were able to create awareness on the provision of varieties of earplugs to increase employees' compliance with the proper use of hearing protectors. Since this type of study has never been done at this facility, the study data set and report will serve as a baseline for the facility's HCP management.

Limitations

We were not able to analyze the facility's audiometric data to evaluate the quality of the hearing conservation program and to correlate audiometric data with questionnaire responses. We were unable to monitor employees' work practices. We were also unable to evaluate how maintenance department employees' insert earplugs.

RECOMMENDATION

We recommend the following to the management, supervisors, and the employees at the facility:

Management

1. Perform holistic evaluation of the HCP.
2. Provide choices of earplug for employees.
3. Consult a noise control engineer to reduce sound levels.
4. Further sampling of personal noise levels below 85 dBA.

Safety supervisor/ line supervisor

1. Continuously training employees' on the proper way of inserting earplugs.
2. Educate employees on the importance of protecting their hearing.
3. Evaluate the use of dual protection.

Employees

1. Insert earplug before putting on hard hat.
2. Use HPD around loud noise correctly.

CONCLUSION

This study demonstrated that production floor and maintenance employees at a meat processing facility are exposed to hazardous noise, and this put them at risk of developing NIHL. Adequate training on the proper use of earplugs, and provision of varieties of earplug may increase employees' compliance with the proper use of hearing protectors.

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APPENDIX

University of Nebraska Medical Center

BREAKTHROUGHS FOR LIFE.

NOISE EXPOSURE AND HEARING ASSESSMENT QUESTIONNAIRE

The purpose of this questionnaire is to understand your noise exposure and hearing loss perception. Please answer all the questions to the best of your ability. This questionnaire will take approximately 5-10minutes to complete. Thank you.

Name: ________________________________ Gender: (Check one) □ Male □ Female

Age: _______________

1. How long have you been working at Tyson Foods in Omaha? ___ Years / ___months
2. How many hours do you work weekly? _______________
3. What is your current job title? _____________________
4. Do you or have you ever participated in any of the following activities?

Activities		If **Yes,** did you wear hearing protection device (earplugs or earmuff)	
Rock band/Loud music	□ Yes	□ Yes	□ No
Motorcycling	□ Yes	□ Yes	□ No
Car racing	□ Yes	□ Yes	□ No
Trap shooting/ Firing range	□ Yes	□ Yes	□ No
Hunting	□ Yes	□ Yes	□ No
Using chain saw	□ Yes	□ Yes	□ No
Using farm machinery	□ Yes	□ Yes	□ No
Working with power tools	□ Yes	□ Yes	□ No
Lawn mowing grasses	□ Yes	□ Yes	□ No
Others, please list ______________________________			

5. Do you experience ringing in your ears?

□ Yes □ No □ I do not know.

If yes, does it improve after few hours or the next day? ________________________

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6. Outside of work, I use hearing protection whenever I am around loud noise.

□ Yes □ No □ I do not know if the noise is too loud.

If yes, what type of hearing protection do you use? ___________________

7. How often do you have trouble hearing? (Check one)

□ Daily □ Often □ Occasionally □ Rarely □ Never

8. How often do you have trouble hearing a speaker at a party or in a group? (Check one)

□ Daily □ Often □ Occasionally □ Rarely □ Never

9. How often do you have trouble hearing speech in a face-to-face conversation? (Check one)

□ Daily □ Often □ Occasionally □ Rarely □ Never

10. How often do you have trouble hearing speech on a telephone? (Check one)

□ Daily □ Often □ Occasionally □ Rarely □ Never

Service Learning/Capstone Experience Reflection

The service learning/ capstone experience opportunity was my first intense research experience with respect to occupational health and safety, which allowed me to: (1) gain more experience regarding safety issues and concerns in a meat processing facility; (2) understand the facility's safety programs; (3) work intensely with industrial hygiene equipment; (4) communicate with lay audience (immigrant workers) despite the language barrier; and (5) work as a team with the facility's employees'. Additionally, I was able to gain more experience on critical thinking related to occupational health and statistical application in real time research. I was also able to learn and understand the way Tyson Foods Omaha Bacon Plant operates, the facility's safety issues and the available safety programs.

During my service learning/capstone experience, I was able to (1) train seventy-one production floor employees, and three food safety and quality department employees on the proper use of earplugs following the three steps: (i) roll (ii) pull the ear (iii) insert; (2) educate employees on noise exposure effects and the importance of using HPD; (3) Develop a pre and post-test training materials for the facility which can be used to assess employees noise exposure knowledge and how they protect their hearing; (4) Develop pictorial warning signs that can be placed around the production floor. My professional certification as a certified occupational hearing conservationist was the skill that permitted and allowed me to execute these activities.