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Assessment of Occupational Exposure to Noise among Sawmill Workers in the Timber Processing Factories

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ABSTRACT

In the workplace, exposure to noise levels at or above 85 dB(A) can increase the risk for the development of noise-induced hearing loss (NIHL). Sawmill workers are continuously exposed to noise levels above 85 dB(A) and they had to raise their voices when they communicate if they are 1 m away from each other. The study was conducted to measure and determine the time-weighted average (TWA) occupational exposure levels to noise in the timber processing factories and compare the results with the noise rating limits. Personal and area noise survey was undertaken using a calibrated SV104IS noise dosimeters (Svantek, Poland) and integrating type 1 sound level meter (Soundpro SE/DL, U.S.A.). Data was analyzed using Microsoft Office Excel 2019 Analysis Tool Pak for descriptive statistics. Both the geometric means and standard deviation as well the minimum and maximum values were determined. The geometric mean (GSD) for area noise exposure levels at sawmill A was 90.05(8.02) dB(A) while at sawmill B was 90.14(7.94) dB(A). Furthermore, the geometric mean (GSD) for personal noise exposure level at sawmill A was 92.26(4.35) dB(A) while at sawmill B was 92.24(2.65) dB(A). The results revealed that sawmill workers were exposed to high noise level above the 85 dB(A) noise rating limit and were at moderate-to-high risk of suffering from NIHL.

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Introduction

High levels of noise in the environment is one of the most common global occupational health hazard (Nandi and Dhatrak 2008; Nelson et al. 2005; Rabinowitz 2000; Themanna and Masterson 2019). Workers in the mining, construction, manufacturing and agricultural sector are exposed to high noise levels which may impair their hearing (Concha-Barrientos, Campbell-Lendrum, and Steenland 2004; Gerges et al. n.d.; Nelson et al. 2005; Nandi and Dhatrak 2008; Tikka *et al.* 2017). Previous studies have indicated that exposure to loud noise for a longer duration can damage the hair cells of the cochlear in the inner ear leading to irreversible sensorineural hearing loss (Azizi 2010; Basner et al. 2014; Hong et al. 2013; Nandi and Dhatrak 2008).

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Ahmed et al. (2001) conducted a noise survey at the factories in the Eastern Province of Saudi Arabia to determine the levels of occupational exposure to noise among the employees. They reported that the overall noise levels recorded at the two factories ranged from 72 to 102 dB(A) and 75% of the workers were exposed to noise levels above the 85 dB(A) recommended exposure level (REL) of the National Institute for Occupational Safety and Health (NIOSH). In the said study 25% of workers were exposed to noise levels above the 90 dB(A) permissible exposure limit (PEL) established by the Occupational Safety and Health Administration (OSHA). Furthermore, 61% of workers exposed to noise level above 85 dB(A) were reported to have never used the hearing protective devices (HPDs), while 38% had hearing impairment that was 8-fold higher than that found in the non-exposed subjects.

More than 30 million workers in the United States of America (USA) and 4 to 5 million workers in Germany are exposed to high noise levels which is defined by the World Health Organization (WHO) as hazardous noise (Concha-Barrientos, Campbell-Lendrum, and Steenland 2004). The noise levels generated at the sawmills vary greatly with the activities being performed and the type of equipment being used (Hong 2005). Normally, the levels of exposure exceed the lower exposure action value of 80 dB(A) and the upper exposure action value of 85 dB(A) at which the use of HPD is mandatory and the 87 dB(A) occupational exposure limit that takes into account the attenuation level of the HPD (European Commission 2020; May 2000). Dost (1974a) carried out a noise survey at the California lumber mill and reported the highest average noise level of 106 dB(A) for the tail sawyer, 107 dB(A) for the chipper tender and 115 dB(A) for the planner machine that were above the upper exposure action value of 85 dB(A) and the second paper reported the highest noise levels of 104.2 dB(A) for the planer and 104.5 dB(A) for the tail sawyer (Dost 1974b). In another study conducted by Ayaz (1991) at the Pakistanian sawmills, an average noise levels ranging from 90 to 113 dB(A) was reported. It was reported that the sawmill workers were at a considerable highest risk of suffering from hearing disability and noise induced occupational health disorders than their counter parts in other countries. However, a noise survey conducted by Ruedy, Lamb, and Johnson et al. (1976) reported the noise levels ranging from 91 to 109 dB(A) for the sawmill machines. Likewise, continuous exposure to noise levels above 85 dB(A) is the leading cause of NIHL (Cantley et al. 2015; Hong et al. 2013; Phillips, Henrich, and Mace 2010; Rabinowitz 2000). This is a bilateral hearing loss with an audiometric notch at the frequencies of 3, 4 and 6 kHz with a recovery at 8 kHz (Chang et al. 2011; Le, Straatman, and Lea et al. 2017; Leensen, van Duivenbooden, and Dreschler 2011; May 2000). This audiometric notch deepens and slowly advances toward lower frequencies if noise exposure continues (Rösler 1994).

It has been reported that the use of ototoxic drugs such as aminoglycosides, ototoxic and non-ototoxic chemical substances such as toxic solvents in paint or organophosphate pesticides as well as aging, smoking cigarette, heat exposure, diabetes, rheumatoid arthritis and exposure to high noise level above 85 dB(A) can increase the risks of developing NIHL (Ferrite and Santana 2005; Gan, Davies, and Demers 2011; Hong et al. 2013; Mizoue, Miyamoto, and Shimizu 2003; Phillips, Henrich, and Mace 2010; Pouryaghoub, Mehrdad, and Mohammadi 2007). Exposure to high noise level can also increase the risk of auditory and non-auditory health effects such as annoyance, sleep disturbance and cardiovascular health, etc (Basner et al. 2014; Chang et al. 2011, 2013; Driscoll, Milk, and Burgess 2009; Münzel et al. 2014; Sbihi, Davies, and Demers 2008; Stansfeld and Matheson 2008). Moreover, prolonged exposure to noise levels above 85 dB(A) can also elevate systolic and diastolic blood pressure in males, thus increasing the risk of hypertension (Chang et al. 2013; de Souza, ARS, and Moura 2015; Driscoll, Milk, and Burgess 2009; Sbihi, Davies, and Demers 2008). Males loose more hearing than females due to no adherence to the regulations and use of HPDs (Lie et al. 2016; Nelson et al. 2005).

The South African government had set a noise rating limit of 85 dB(A) for an 8 hours period, their action plan includes a stricter enforcement of legislation and better implementation of hearing loss prevention program to reduce noise levels at the sawmills. Five-hundred (500) OHS inspectors has been employed to offer specialized advice on good practise and information on employers to reduce NIHL. South Africa government is also rolling out awareness programs to reduce noise exposure at the sawmill through designing and modification of machinery and isolation and enclosure of noise sources as well as control of noise exposure along the path through separation of workers as well as the use of HPDs. There is a growing concern about the high noise levels at the timber processing factories and the prevalence of NIHL which may have a detrimental impact on workers' health and quality of life (Concha-Barrientos, Campbell-Lendrum, and Steenland 2004; May 2000; Picarda, Girard, and Simard et al. 2008; Suter 2002). Many countries have set occupational exposure limits of 85 and 90 dB(A) for an 8-hour period. The choice of the standards is based on the ethical, social, political and economic factors (Fisnea and Oktenb 2013; I-INCE International Institute of noise control Engineering (Ed.) 1997; Lester, Malchaire, and Arbey et al. 2001). To date, few studies have been conducted in South Africa at the timber processing factories to investigate the level of occupational exposure to noise. This study was conducted to determine the TWA occupational exposure to noise in the two timber processing factories and compare the results with the noise rating limits.

Material and Methods

Location and Sampling Sites

The study was conducted at the two sawmill factories located within the Gert Sibande District Municipality of Mpumalanga Province in South Africa. The selection of the sawmills was based on their size, number of workers, location and the type of machine that were used in the processes. The sampling sites that were covered for area noise assessment at sawmill A included the door house room, finger joint at the machine area, knotty pine and profile door, saw shop, workshop, dry mill, boiler house, green chain and wet mill. At sawmill B, the sampling sites included for noise assessment were at the door house room, finger joint at the machine area, knotty pine and profiles door, saw shop, workshop, dry mill, boiler house, green chain and wet mill.

Study Population and Selection of Participants

Sawmill workers who had been in continuous employment for a minimum period of 6 months at the sawmill factories were included in the study. The selection of participants was done according to the job titles. The workers employed as chipper operators, unscramble operators, log operators, welders, stopper operators, bell drivers, profile cutters, log frame operators, general workers, trim saw operators, staffer operators, profile cutters, door cutters, bell drivers, house keepers and grader operators were included as participants.

Sampling Procedure for Personal Noise Monitoring

A cross-sectional survey was conducted whereby personal noise exposure results were monitored at the sawmills using calibrated SV104IS noise-dosimeters (Svantek, Poland). Twenty-two participants (12 at sawmill A and 10 at sawmill B) who gave consent to take part in the study were randomly selected. Before placing the dosimeters on the workers, the purpose of the study as well as the procedures to be followed was explained to them and after that the consent forms as well as the personal noise exposure recording sheet were completed. The dosimeters were attached on the mid top of the workers' shoulder approximately 10 cm (0.10 m) on the most exposed ear with the microphone just about few centimeters above the shoulder following the South African National Standard (SANS 10083) and Svantek manufacture instructions when monitoring personal noise exposure at the sawmill (South Africa National Standard (SANS 10083) 2013; Svantek 2015; Svantek 2016). The dosimeters were switch on to run for the duration of 8-hour period. The survey was conducted from 8 h00am to 4h00 pm excluding lunch and tea time. Windshields were used to cover the microphones and care was taken to avoid exposing the dosimeters to any vibration while sampling. Environmental

condition such humidity, temperature, etc. did not have any influence on the monitoring results and the equipments were calibrated before and after and the calibrations remain within the calibration parameters. The workers who wore the dosimeters were constantly monitored while performing their tasks to ensure that the equipment was operating effectively. The dosimeters were removed from the workers at the end of the shift and the personal noise exposure recording sheets were completed and the instrument was switched off.

Sampling Procedure for Area Noise Survey

Twenty-two areas were selected at the sawmills (11 at sawmill A and 11 at sawmill B) for evaluating area noise using a calibrated type 1 integrating sound level meter (Soundpro SE/DL, U.S.A.). The instrument was calibrated before and after sampling using casella CEL-120/2 sound level calibrator and the calibration remained within the acceptable range of ± 0.5 dB during calibration. The meter was attached on a tripod stand, with the microphone positioned at the ear height or hearing zone about 1.5 m above the ground and 1.2 m away from the reflecting surfaces following the South African National Standard (SANS 10083) and TSI Incorporated manufacture instruction when monitoring area noise levels at the sawmills (South Africa National Standard (SANS 10083) 2013; TSI Incorporated 2018). The noise levels for area noise monitoring at 5 meters, 10 meters, 15 meters and 20 meters' distance was not recorded as the results of data that decreases as you move a distance away from the noise sources. Dost (1974a) indicated that each time the distance is doubled; the noise level falls by 6 dB. The number of area measurements selected deviated from the recommended minimum number of three in view of the practical constraints. Each individual measurement was taken over a long duration to be representative of the exposure levels in each task or area. The measurement results were recorded on the area noise exposure recording sheet. A sketch of the noise map showing points of noise exposures in each area bellow 82 and above 85 dB(A) was generated.

Ethical approval (clearance number: UFS-HSD2019/2236/3006) was obtained from the Health Science Research Ethics Committee of the University of the Free State. Permission to conduct the study was granted by the managers in charge of the sawmill factories and the participants gave consent to take part in the study. Participation in the study was voluntary and participants were allowed to withdraw at any time.

Statistical Analysis

Data was analyzed using Microsoft Office Excel 2019 Analysis Tool Pack to obtain a summary of descriptive statistics. The geometric means, standard

deviations, minimum and maximum values were calculated. The *T*-test was used to compare the mean time-weighted averages of noise exposure from sawmill A and B. A significance level of 0.05 was used.

Results

Area Noise Exposure Level

The summary statistics of area noise exposure level from sawmill A and B is shown in Table 1. The mean (SD) for area noise exposure level at sawmill A was 90.42(8.41) dB(A) with a geometric mean (GSD) of 90.05(8.02) dB(A). Similarly, the mean (SD) for area noise exposure level at sawmill B was 90.5 (8.33) dB(A) with geometric mean (GSD) of 90.14(7.94) dB(A). As shown in Table 1, the results ranged from 75.9 to 103.5 dB(A) at sawmill A and 75.8 to 103.1 dB(A) at sawmill B.

A summary statistics of personal noise exposure level from sawmill A and B is shown in Table 2. The results show that the mean (SD) for personal noise exposure level at sawmill A was 92.36(4.54) dB(A) with a geometric mean (GSD) of 92.26(4.35) while at sawmill B was 92.28(2.79) dB(A) with a geometric mean (GSD) of 92.24(2.65) dB(A). Furthermore, the results ranged from 86.3 to 101.2 dB(A) at sawmill A and 88.3 to 96.9 dB(A) at sawmill B.

Table 3 shows the proportion of samples for personal noise exposure level that are either below or above the action level and noise rating limit. The TWA exposure level for all 22 samples recorded from the sawmills, were above both the action level of 82 dB(A) and 85 dB(A) noise rating limit and were below 105 dB(A) where instant NIHL may occur.

Table 1. Summary statistics of area noise results from sawmill A and B.

Sawmill	Noise type	Number of areas sampled	GM dB(A)	GSD	Median	Range	Mean (SD) dB(A)	Min	Max	*p*-value*
Sawmill A	Area noise survey	11	90.054	8.023	92.5	27.6	90.4(8.41)	75.9	103.5	0.982
Sawmill B	Area noise survey	11	90.143	7.939	92.9	27.3	90.5(8.33)	75.8	103.1	

**T*-test

Table 2. Summary statistics of personal noise results at sawmill A and B.

Sawmill	Noise type	Number of personnel samples	GM dB(A)	GSD	Median	Range	Mean (SD) dB(A)	Min	Max	*p*-value*
Sawmill A	Personal noise	12	92.258	4.351	91.65	14.9	92.36(4.54)	86.3	101.2	0.961
Sawmill B	Personal noise	10	92.242	2.648	92.15	8.6	92.28(2.79)	88.3	96.9	

**T*-test

Table 3. Proportion of samples for personal noise exposure level below or above the action level and noise rating limit from sawmill A and B.

Sawmill	Type of noise	N	<82 dB(A)	≥82 & <85	≥85 & <105 dB(A)
Sawmill A	Personal noise	n = 12			12
Sawmill B	Personal noise	n = 10			10
	Total	22	0	0	100% (n = 22)

Table 4. Proportion of samples for area noise exposure level below or above the action level and noise rating limit from sawmill A & B.

Sawmill	Type of noise	N	<82 dB(A)	≥82 & <85	≥85 & <105 dB(A)
Sawmill A	Area noise	n = 11	2	2	7
Sawmill B	Area noise	n = 11	2	2	7
	Total	22	18% (n = 4)	18% (n = 4)	64% (n = 14)

The results in Table 4 show the proportion of samples for area noise exposure level that are either below or above the action level and noise rating limit. The noise level of 14 samples recorded at the sawmills exceeded both the action level of 82 dB(A) and the noise rating limit of 85 dB(A). The TWA noise exposure levels for four samples exceeded the action level but were below the noise rating limit. Furthermore, the TWA noise exposure levels for the other four samples were below both the action level and noise rating limit.

Eight-hour TWA Personal Noise Exposure Levels

The results in Table 5 shows the eight-hour TWA personal noise exposure levels at sawmill A and B. A total of 22 samples were obtained from sawmill A and B (12 samples at sawmill A and 10 samples at sawmill B). The highest exposure level of 101.2 dB(A) was recorded from general worker while the lowest exposure of 86.3 dB(A) was recorded from a Stopper operator at Sawmill A. In sawmill B, the highest exposure level of 96.9 dB(A) was recorded

Table 5. Eight-hour TWA personal noise exposure levels from sawmill A and B.

Sawmill A			Sawmill B		
Sample no.	Participant job tittle	$L_{Req,\ 8h}$ dB(A)	Sample no.	Participant job tittle	$L_{Req,\ 8h}$ dB(A)
1	Chipper operator	99.9*	1	Grader operator	92.5*
2	Unscramble operator	92.1*	2	Staffer operator	92.9*
3	Log operator	89.9*	3	Grader operator	96.9*
4	Welder	89.0*	4	Profile cutter machine operator	88.3*
5	Stopper operator	86.3*	5	Door cutter	89.5*
6	Trim saw operator	89.3*	6	Trim saw operator	91.8*
7	Bell driver	93.6*	7	Bell driver	93.6*
8	Bell driver	95.4*	8	House keeper	89.7*
9	Profile cutter operator	88.3*	9	Chipper operator	96.2*
10	Log frame operator	91.2*	10	Grader	91.4*
11	General worker	101,2*			
12	Trim saw operator	92.1*			

*Personal noise exposure levels above 82 dB(A) action level and 85 dB(A) noise rating limit.

Table 6. Average 8-hour TWA area noise exposure levels from sawmill A and B.

Sawmill A			Sawmill B		
Sample no.	Area/place	Average $L_{Req,8h}$ dB(A)	Sample no.	Area/place	Average $L_{Req,8h}$ dB(A)
1	Door house	91.7*	1	Door house	91.9*
2	Finger joint machine	92.5*	2	Finger joint machine	92.9*
3	Knotty pine & profiles house	97.9*	3	Knotty pine & profiles house	98.0*
4	Saw extractor machine next to door house	80.4	4	Saw extractor machine next to door house	80.8
5	Saw shop	83.4**	5	Saw shop	83.6**
6	Workshop	75.9	6	Workshop	75.8
7	Dry mill	97.6*	7	Dry mill	97.7*
8	Boiler house	84.1**	8	Boiler house	84.2**
9	Green chain	93.5*	9	Green chain	93.5*
10	Wet mill	94.1*	10	Wet mill	94.0*
11	Chipper machine next to drymill	103.5*	11	Chipper machine next to dry mill	103.1*

*Area noise levels above 85 dB(A) noise rating limit.
**Area noise levels above 82 dB(A) action level but bellow 85 dB(A) noise rating limit.

from grader operator while the lowest exposure level of 88.3 dB(A) was recorded from a profile cutter at sawmill B

Average 8-hour TWA Area Noise Exposure Levels

The results in Table 6 shows the average $L_{\text{Req, 8h}}$ area noise exposure levels at sawmill A and B. A total of 22 samples were recorded at sawmill A and B. The highest exposure level of 103.5 dB(A) was recorded at a chipper machine next to dry mill while the lowest exposure of 75.9 dB(A) was recorded at the workshop at sawmill A. In sawmill B, the highest exposure level of 103.1 dB(A) was recorded at a chipper machine next to dry mill while the lowest exposure level of 75.8 dB(A) was recorded at the workshop at sawmill B

Discussions

The study was conducted to investigate the TWA noise exposure levels at the sawmill factories. All the measurements for personal noise exposure level obtained at the sawmills were at or above the level of 85 dB(A) NIOSH REL but below the 105 dB(A) level where instant NIHL may occur. This finding was inconsistent with the results obtained by Neitzel et al. (1999). In the said study which was conducted at a construction site, the mean OSHA TWA exposure level for 338 samples was 82.8 dB(A) ± 66.8 dB(A), while the mean NIOSH/ISO TWA exposure level for 174 samples was 89.7 dB(A) ± 66.0 dB(A). In addition, 40% of the OSHA TWAs noise exposure levels exceeded 85 dB(A) NIOSH REL, while 13% exceeded the 90 dB(A) OSHA PEL. Likewise, 43% OSHA TWAs noise exposure levels of the 338 (12.7%) exceeded the 90 dB(A) OSHA PEL and 135 of the 338 (39.9%) exceeded the OSHA action level of 85 dB(A). In contrast, 82% of the 174 NIOSH/ISO TWAs

noise exposure level exceeded 85 dB(A) and 45.3% exceeded the 90 dB(A) OSHA PEL.

The lowest personal noise exposure of 86.3 dB(A) was recorded from the stopper operator, while the highest noise level of 101.2 dB(A) was recorded from the general worker at sawmill A. Furthermore, the lowest noise level of 88.3 dB(A) was recorded from the profile cutter machine operator and the highest noise level of 96.9 dB(A) was recorded from the grader operator at sawmill B. The results are not consistent with that of Thepaksorn et al. (2017) who reported the lowest personal noise exposure level of 88.43 dB(A) from a worker working performing vacuuming and wood preservation processes and 88.43 dB(A) from a worker working at the grading, packaging and storage department. Furthermore, Thepaksorn et al. (2017) reported the highest personal noise exposure level of 94.4 dB(A) from a worker who was sawing lumber into sheets. However, the mean (SD) personal noise exposure level at sawmill A was 92.36(4.54) dB(A) while at sawmill B was 92.28(2.79) dB(A). Twenty-three percent of the samples for personal noise level obtained at the two sawmills were above the 85 dB(A) NIOSH REL, while 77% were above the 90 dB(A) OSHA PEL. Moreover, the results are inconsistent with the study by Davies et al. (2008) who reported the mean (L_{eq},8 hr) personal noise exposure level of 91.7 dB(A). In the said study, only 4 samples out of the 52 jobs that were sampled were below the 85 dB(A) NIOSH REL, while 28 jobs had a mean exposure level above the 90 dB(A) OSHA PEL and four jobs had a mean exposure level above 100 dB(A).

Koehncke, Taylor, and Taylor et al. (2003) conducted a similar study at the Alberta sawmills in Canada and reported that 10% of personal noise exposure measurements were below the 85 dB(A) level of the Alberta 8-hour exposure limit, while 27% of the samples were at or above 95 dB(A). They reported that 82% of the samples for personal noise exposure level obtained at the sawmills at or above 95 dB(A) were obtained from the planer infeed operator, while 62% of the samples were obtained from the planermen. In the present study, 18% of the samples for personal noise level at or above 95 dB(A) were obtained from the general worker [101.2 dB(A)], grader operator [96.9 dB(A)], chipper operator [96.2 dB(A)] and bell driver [95.4 dB(A)]. Furthermore, 23% of the samples were above 85 dB(A) and 59% were above 85 dB(A) but bellow 95 dB(A).

The lowest area noise level recorded at sawmill A was 75.9 dB(A) from the workshop and the highest was 97.9 dB(A) recorded at knotty pine and profile door. The area noise level of 97.6 dB(A) was recorded from the dry mill. Moreover, the lowest noise level of 75.8 dB(A) was recorded from the workshop at sawmill B and the highest noise level of 98.0 dB(A) was recorded at knotty pine and profile door; the area noise level of 97.7 dB(A) was recorded at the dry mill. These results were below the 130 dB(A) average noise level recorded by Ratnasingam et al. (2010) in

a study conducted at the rough milling section of the wooden furniture industry in South East Asia. Furthermore, the noise levels ranging from 85 to 110 dB(A) was recorded by D'Antonio et al. (2013) in Italian sawmills while Verma et al. (2010) recorded the noise levels that ranged from 55 to 117 dB(A) at the Ontario sawmills. In the present study, 36% of the samples for area noise level obtained at the sawmills were below the 85 dB(A) NIOSH REL and the ACGIH TLV while 64% of the samples were above the 90 dB(A) OSHA PEL. These findings are inconsistent with those of Thepaksorn et al. (2017) who reported the lowest average noise level of 86.0 dB(A) recorded at the grading, packaging and storage department and the 88.4 dB(A) highest average noise level recorded at the area for sawing of the lumber into sheets.

Choudhari, Dhote, and Patil (2011) carried out a similar study at the sawmills and reported the noise level of 90 dB(A) for the silc machine, 108 dB(A) for the chain saw and 101 dB(A) for the planning machine. Ugbebor and Yorkor (2015) reported the results for area noise levels measured during monitoring exercise at the Rumuosi sawmill ranging from 88.0 to 94.1 dB(A) with a mean (SD) of 92.49 ± 1.91 dB(A); the measured noise levels at Mile 3 was reported to range from 84.4 to 94.2 dB(A) with a mean (SD) of 92.44 ± 3.41 dB(A). Furthermore, the field measurements result at Mile 1 ranged from 66.2 to 94.3 dB(A) with a mean (SD) of 92.0 ± 9.55 dB(A). These findings are inconsistent with the findings of the present study because the highest area noise level recorded at sawmill A was 103.5 dB(A) at the chipper machine next to the dry mill while at sawmill B was 103.1 dB(A). Moreover, the results differ with those of the study by Ratnasingam et al. (2010) who reported an average noise level of 150 dB(A) from the sawmill molder at the rough mill section and the 110 dB(A) noise level from the high speed router at the machine section.

Aremu, Aremu, and Olukanni (2015) conducted a study at the sawmill factories and reported the background noise level ranging from 58.1 to 64.86 dB(A), while the machine equivalent noise level recorded ranged from 81.1 to 112.3 dB(A). The maximum noise level for a combination of machine operation ranged from 105.6 to 121.7 dB(A) and 73% of the measurements obtained were above the 85 dB(A) NIOSH REL. The results of the said study differ with the results of the present study because only 64% of the area noise samples obtained were above the 85 dB(A) NIOSH REL. However, Boateng and Amedofu (2004) conducted a similar study at the printing mill, corn mill and sawmill and reported the noise level above the 85 dB(A) noise rating limit at the corn mills and saw mills, while the average noise level measured at the printing mill was 85 dB(A). A high proportion of workers at the corn mills and sawmills and a few at the printing mill reported to have experienced some form of NIHL. Moreover, in the said study, a highly significant correlation was found between the noise exposure levels, duration of exposure and

development of NIHL among employees at the corn mills and saw mills except at the printing mill.

Ebe et al. (2019) in their study reported that the noise levels at the sawmills ranged from 96.15 to 101.65 dB(A) at Ogbosisi and 93.19 to 94.96 dB(A) at an industrial Market in Umuonyeali Mbieri. Ugwoha, Momoh, and Arusuraire (2016) performed the similar study and reported the background noise levels ranging from 70.58 to 79.70 dB(A) at Mile 3, Mile 1 and Rumuosi sawmill; the noise levels recorded from the machines ranged from 89.76 ± 0.09 to 100.49 ± 0.20 dB(A) at Mile 3, 89.81 ± 0.13 to 97.00 ± 0.46 dB(A) at mill 1 and 89.76 ± 0.07 to 100.10 ± 0.53 dB(A) at Rumuosi sawmill. In addition, Robinson et al. (2015) conducted a cross-sectional study among 124 woodworkers (88 carpenters and 36 sawyers) using pure-tone audiometry between the frequencies of 0.5 and 8 kHz to ascertain participants' hearing status and assess noise levels at selected workplaces. In the said study, it was reported that 31% of carpenters and 44% of sawyers met the 7% criteria for NIHL, while 17% met the WHO criteria for hearing impairment. The recorded noise levels at various workplaces ranged from 71.2 to 93.9 dB(A) and were inconsistent with the results of the present study with a range of 86.3 to 101.2 dB(A) at sawmill A and 88.3 to 96.9 dB(A) at sawmill B.

Most companies give limited or no attention to noise controls and relied primarily on HPD to prevent hearing loss yet 38% of employees do not utilize HPD regularly (Daniell, Swan, and McDaniel et al. 2006). Depending solely on HPDs use is not a recommended approach in the real industry because a questionnaire-based research studies have shown its usage rates to be less than 50% (Neitzel et al. 1999). The HPDs that were used by the participants of the present study had an NRR of 25 dB and the minimum NRR for a real world was estimated to be 9 dB when using the derating formula. The NIOSH and OSHA has recommended a 50% de-rating factor depending on the type of HPD subject to fit test (NIOSH 1998). Daniell, Swan, and McDaniel et al. (2006) carried out a study in the sawmills to assess the effectiveness of using HPDs among sawmill workers and found out that HPDs use were high when hearing conservation program (HCP) was mostly complete, which indicated that the under-use of HPD was in some instance attributed by incomplete or inadequate company efforts.

Likewise, Mandryk, Alwis, and Hocking (2000) conducted a study at the Australian sawmills and found out that the prevalence of frequent headaches among sawmill workers was significantly higher among the dry mill and green mill workers as compared to the control group. They indicated that it was unlikely for frequent headaches to be attributed by exposure to noise because all workers observed were wearing HPDs during their shift. Aremu, Aremu, and Olukanni (2015) in their study indicated that the most prominent health complaints reported by sawmill workers was tinnitus (96.6%), headache (86.6%) and hearing loss (71.9%). However, Thepaksorn et al. (2019) in their study reported that about 25% of the workers were trained on the proper use of PPE and half of

them never or rarely wore PPE while working and the prevalence of NIHL was 22.8%. They reported that male workers reported a significantly increased risk of NIHL than female workers. In addition, 58% of the workers reported that they feel uncomfortable, while 42% reported lack of awareness on HPD and 25% feel that the devices create barrier in communication. This finding differs with the present study because the participants of the exposed group (87%) reported always wearing PPE while on site and the control group (75%) reported wearing it sometimes. The reason for not using PPE by the exposed group (48%) was due to its unavailability; all the participants of the control group stated other reasons.

Chadambuka et al. (2013) conducted a study at the mine clinic among 169 workers aged from 19 to 63 years who were tested on both ears for NIHL. Workers experienced NIHL due to working in noisy environments (53.2%), improper or nonuse of hearing protection (40.8%) and intermittent but very loud sounds (5.9%). About 140 (82.8%) of the employees reported using HPDs because they were always exposed to noise and 13 (7.5%) reported using HPD whenever they entered a noise zone. One hundred and sixteen (68.6%) of the workers reported using earplugs, while 53 (31.4%) used earmuffs and about 160 (94.7%) of workers reported that they were trained on the use of HPDs. Moreover, the noise levels recorded were 94 dB(A) at the Plant Processing area, 102 dB(A) at the underground mining area and 103 dB(A) at the underground workshop. Sixty-two workers (36.7%) reported having NIHL and the usage of hearing protector was high among those exposed to noise levels of above 85 dB(A) and 95 dB(A); the self-reported use of HPDs was 84% for 73% of the time. (Davies et. 2008).

Presently, most sawmill workers are not enrolled in the effective hearing loss conservation programs (HCP) due to the nature of their work and the work-place locations. Percentage of NIHL can be lowered through a broader approach including noise exposure prevention, identification of noise sources, periodic audiological evaluation of those working in noise zones and engineering control backed up by the use of fit-tested HPDs. The procedure adopted can include noise measurements, audiometric evaluation and assessment of clinical history. The secretion of catecholamine can decrease when workers wore hearing protection against noise exposure (National Institute for Occupational Safety and Health (NIOSH) 1998; Stansfeld and Matheson 2003).

Conclusion

Sawmill workers were exposed to noise level above 82 dB(A) action level and 85 dB(A) noise rating and are at moderate-to-high risk of suffering from NIHL. Furthermore, exposure to noise levels above the action level and noise rating limit can cause auditory and non-auditory health effects such as cardiovascular disease, psychological stress and hypertension (Neitzel, Andersson, and Andersson 2016; Neitzel, Fligor, and Organisation 2017). In addition, exposure to noise levels above 75 dB(A) among men may increase the risks of coronary heart diseases (CHD),

while exposure to noise levels between 75 and 80 dB(A) for less than 20 years may increase risks of ischemic heart disease (IHD) (Dzhambov and Dimitrova 2016; Eriksson 2019). In this study, the noise exposure levels among sawmill workers have been determined and this information is necessary to assist the sawmill industry to implement control measures to mitigate exposure. It is recommended that the following measures should be implemented at the sawmill factories to reduce sawmill workers' exposure to high noise level:

- The machines that generate high noise level should be substituted with those that generate low noise level. The noise levels of machinery should be checked before purchasing it and the sawmill factories should have a policy of purchasing only equipment that generates low level of noise.
- The noise sources should be isolated in enclosures. A barrier should be placed between the noise sources and employees.
- Workers who are exposed to high noise levels should be relocated to other areas with low noise levels. There should be a rotating schedule of workers between less noisy and high noisy work environment which may reduce the risk of substantial hearing loss among workers.
- An operation of noisy machines simultaneously at any time should be avoided to reduce the noise exposure level.
- The number of workers who are exposed to high noise level at any given time should be reduced. Furthermore, the time spent in the noisy environment should be limited in addition to wearing of HPD.
- The wearing of HPDs should be made compulsory to workers in noise zones to prevent hearing loss.
- Moreover, education and training should be provided to the workers about the proper use, maintenance and storage of HPD.
- Furthermore, workers should undergo audiometric tests regularly for early detection and prevention of the hearing loss.

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