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Noise Exposure Levels And Associated Effects Among Workers In Heavy Machine Maintenance Workshops: A Study In Gold Mining Site

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Abstract:

Background: Mining sector is among the fastest growing economies worldwide. The processes associated with mining activities generate tremendous noise. Excessive noise exposure in the workplace can limit worker's ability to communicate and hear warning signals as well as temporary hearing problems and permanent noise induced hearing loss. This may have huge impact on worker's safety and productivity.

Objective: This study assessed Noise Exposure Levels and Associated Effects among Heavy Machine Maintenance Workshop workers in Gold Mine Site in Tanzania.

Methods: One hundred and nineteen (119) workers at maintenance workshop in gold mine site participated in this cross-sectional study. Information on demographic characteristics, hearing problems experienced and attitudes toward hearing protective devices were collected using questionnaire. Area noise levels were measured at different points in the workshops (n=18) and personal noise samples (n=62) were measured using Larson Davis noise dosimeters. Prevalence of noise induced hearing loss for workers was assessed. Frequencies were generated, logistic regression and chi-square test were used to determine association of the study variables.

Results: All respondents were male with arithmetic mean age 35.1, the mean noise exposure level was 85.68 dB(A). Among workers with recent audiometry, 3.2% had severe hearing loss that required referral, 12.9% had moderate hearing loss (warning level). Prevalence of self-reported hearing problems was (56.5%) for workers with noise exposure of above 85 dB(A). Major hearing problems reported include speech interference (7%), reduction in hearing (56%) tinnitus (31%) and ear infections (6%). About 93.3% of workers regularly using hearing protection devices. There were statistically significant relationships with hearing problems, noise exposure levels, organic solvent used and work duration (p>0.05).

Conclusion: Findings from this study indicate workers in maintenance workshop at gold mine site were exposed to noise levels higher than the occupational exposure limit (OEL) and may develop hearing problems like any other workers in the mine.

Recommendations: The mine management should institute more measures like regular training on hearing protection devices use and hearing conservation program to reduce the risk of developing noise induced hearing loss.

Keywords: Excessive noise, noise exposure, heavy machine maintenance work, noise induced hearing loss, hearing protection devices.

I. BACKGROUND

Mining sector has become the fastest growing economy worldwide. It contributes about 8.5% of Tanzania economic growth, and have contributed about 4% in country's' Gross Domestic Products (GDP) (3) (Cobbert D 2016). With massive development of mining industries there is great concern of environment and health risks that are associated with mining activities. Those impacts include air and water pollution and land degradation as well as effects on workers'

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health and wellbeing (WHO Review 2015) and (WHO Technical review 2019). Excessive noise exposure in the workplace can limit workers' ability to communicate and hear warning signals and can affect their safety and productivity. A more significant risk is that long-term noise exposure increases the risk of hearing problems and hearing loss, with great implications to workers' health, employment prospects and overall quality of life (URT National Environmental Statistics Report).

The major effects associated with excessive exposure to workplace noise is said to be Noise Induced Hearing Loss (NIHL). The prevalence of NIHL at mining industry in Zimbabwe was 37% (Chadambuka et al 2019). A study by Musiba Z, in Tanzania found that the prevalence of NIHL to be about 47% (Musiba Z 2015). And the study on prevalence of NIHL in South Africa was observed to be 39.3% (Satheley E 2015). Noise is one of the important harmful factors in the working environment which is produced by various machineries and processes. There are several factors which contribute to hearing problems, these include infection and injuries (17.1%), ageing (28%), inborn hearing problems (4.4%), and prolonged noise exposure especially at work place contribute about (33.7%) of hearing problems worldwide (Mutagwaba et al 2018).

Maintenance is an essential function in mining workplace. Maintenance workers are more likely to be exposed to a wide variety of risks than other employees, which may lead to various occupational diseases and/or injuries. A Spanish working conditions survey indicated a higher exposure of maintenance workers to noise, vibration and different kinds of radiation when compared to the rest of the working population. Studies also indicate that the repair phase poses the greatest risk with 46% of maintenance related accidents (Satheley E 2015). Participants in Gas-fired Electric Plant Workers in Tanzania operation and maintenance departments had a higher mean equivalent sound level (John W et al 2018).

Different regulatory bodies have set occupational exposure limits for workplace hazards including noise. National Institute for Occupational safety and Health (NIOSH) Recommended Occupational Exposure Limit (OEL) for noise exposure is 85 decibels A-weighted at an 8-hr Time Weighted Average (i.e. 85 dB(A) TWA). Exposures above this level are considered hazardous according to NIOSH Occupational noise criteria. The Occupational Safety and Health Administration of Tanzania (OSHA TZ) has set the noise OEL to be 85 dB(A) for 8 hours working time.

This study therefore aims at evaluating personal noise exposure levels and its effects among workers working at heavy machine equipment workshop in Gold mining. The findings will help mining management to improve the current control measures into appropriate and effective control measures. This in turn will help reduce exposures hence improve health and social wellbeing of the workers and community in large. It will help to address important risk factors for noise exposure in maintenance workshops in mining industries and could be useful for building up appropriate interventions for managing noise exposure.

II. METHODS

STUDY DESIGN AND SETTING

This study employed a cross-sectional descriptive study design conducted in August 2019. Noise levels were measured and the associated factors were assessed using questionnaire and walkthrough survey. The study was conducted in maintenance workshops in an active gold mine in North-West of Tanzania. The Gold mine has two major operating maintenance workshops; which are Heavy Machine Engineering workshop (HME) and Engineering Service workshop (ES) Workshop operates in two shifts of 12 hours. Job categories performed at these workshops are mechanical works, auto-electrical services, boiler makers operations, fitting mechanics as well as rigging and scaffolding.

PARTICIPANTS

Total of 119 maintenance workers were included in this study through convenient sampling procedure. Participants for noise exposure survey were obtained using the National Institute for Occupational Safety and Health (NIOSH) Guideline for Random Sampling of Homogeneous Risk Group Workers depending on the number of workers in the sections assumed to be of Similar Exposure Groups total number of workers participated for personal noise exposure assessment were 62 from different job sections.

MEASUREMENTS

Area noise measurement Survey of workshops noise sources and levels was carried out by measuring sound level in each particular area of workshops. An S1.4 Type 2 digital sound level meter (SLM) was used to measure noise level at different points in two workshops, the SLM was placed about 5m from the noise source activity while worker perform their tasks and about 1.2-1.5m above the floor and 3.5 m from away from sound-reflecting structures in the work site. Nine points were measured in each workshop.

Personal noise measurements: Integrated noise dosimeters Larson Davis Spark model number 705+ and 706 were used to measure personal noise exposure levels during 8 hours working time, pre and post calibration was done before and after each measurement. The dosimeter microphone was attached to the workers collar at the hearing zone approximately 10 cm from the ear, the dosimeter was set to run for 8 hours of working shift. After completion the dosimeter was connected to the computer and data were downloaded and presented in excel worksheet.

The dosimeter settings were; Detector (SLOW), Sample Interval (60 seconds), Peak weigh (C), Exchange rate (3dB(A)), Threshold level (80dB(A)), Criterion level (85dB(A)), Criterion duration (8 hours.

The 8-hour Time Weighted Average (8-hr TWA), Sound Exposure (SE) levels and maximum noise peak (Lpeak, max) were recorded. 8-hr TWA was used as a guideline because most of the OEL are using (8-hr TWA), in dB(A) as references (13). The OEL used was 85 decibels, A-weighted, as an 8-hr time-weighted average (85 dB(A) as an 8-hr TWA)

for occupational noise exposure established by the National Institute for Occupational Safety and Health (NIOSH) in 1972 as regarded. Exposures at or above this level are hazardous.

AUDIOMETRY

Audiometry results for 62 participants who were involved in the noise survey were obtained from previous audiometry test records at the mining clinic these are from pre-employment and normal periodic and screening examinations. SmartTone audiometer with serial number 70338 was used to test hearing. Health and safety Executive (HSE)-UK Classification of Audiograms were used to categorize hearing loss as normal, warning and referral. HSE categorization scheme based on sum of hearing at 1, 2, 3, 4 and 6 kHz was used to assess hearing loss.

DATA COLLECTION

Demographic information of the workers (age sex education and job history). Hearing protection usage and attitude, hearing capacity and hearing problems of the workers. Use of organic solvent and ototoxic drugs. The total number of participants who were involved in the questionnaire survey were 119.

DATA ANALYSIS

The data processing and analysis was conducted using SPSS version 22 based on each study objective. Descriptive statistics was performed for all variables. The bivariate and multiple logistic regression were run for assessing association between risk factors that contributed to hearing problems. Multivariate analysis using mixed effects models and logistic regression models was done to explain determinants for noise exposure and hearing loss, respectively confidence interval level of 95% and p-value< 0.05 were considered to indicate statistically significant association between dependent variables and independent variables.

III. RESULTS

SOCIO-DEMOGRAPHIC CHARACTERISTICS OF THE STUDY PARTICIPANTS

The study consisted of 119 participants from different sections at maintenance workshops who were at work at the time of the study making a response rate of 86.2%. All participants were male with mean age of 35.19(SD=7.23) with mode of 33 years range 22 to 51 years. Majority 64(53.8%) of respondents attained secondary education, 23(19.3%) vocational education, 13(10.9) tertiary education and 18(15.1%) primary education. About 93(78.2%) of maintenance workers live outside mine camp and 26(21.8%) live inside the camp. The mean duration of work in noise environment was 7.76 years (SD=3.79), with 5 years mode, minimum duration was 2 years and maximum duration was 20 years. The study participants consist of 37(31.1%) mechanics, 27(22.7%) boiler makers, 25(21.8%) auto electricians, 16(13.4%) rigger operators and 14(11.8) fitter mechanics.

PERSONAL NOISE EXPOSURE LEVELS

Sixty-two personal noise exposure assessment were done for workers in five sections in the workshops (boiler makers, mechanics, rigger operators, auto electricians and fitter mechanics). Mean noise exposure level in 8 hours (TWA) scale was 85.68 dB(A) (SD=6.56) ranging from (68.00 dB(A) to 100.10 dB(A)). Mean noise exposure for mechanics was 85.9 dB(A) (ranging from 73.9 to 99.9) with 11(31.4%) samples exceeding OEL, 85.3dB(A) for boiler makers (ranging from 68 dB(A) to100.1 dB(A)) with 9(5.7%) samples exceeded OEL.

Auto electricians are exposed to mean noise of 86.7 dB(A) (ranging from 78 dB(A) to 98.3dB(A)) with 9(5.7%) samples exceeding noise levels above 85 dB(A). Mean noise exposure levels for fitter mechanics was 87.3 dB(A) (ranging from 71.8 dB(A) to 99. 8dB(A)) with 4(11.5%) exceeding 85 dB(A), rigger operators mean noise exposure 83.3 dB(A) (ranging from 78.9 dB(A) to 92.3 dB(A)) with 2(5.7%) exceeding 85 dB(A) (Table 1).

Job category	N	Mean	Min	Max	>85 dB(A) n(%)	<85dBA (n(%)
Mechanics	21	85.9	73.9	99.9	11(31.4)	10(37)
Rigger operators	8	83.3	78.9	92.3	2(5.7)	6(22.3)
Boiler makers	14	85.3	68	100.1	9(25.7)	5(18.5)
Auto electricians	13	86.7	78	98.3	9(25.7)	4(14.8)
Fitter mechanics	6	87.3	71.8	99.8	4(11.5)	2(7.4%)

Table 1: Noise exposure levels of >85 dB and <85 dB(A) between sections of maintenance workshop (n=62)

PREVALENCE OF SELF–REPORTED HEARING PROBLEMS

Out of 119 workers who were asked for hearing problems using the questionnaire, 32(26.9 %) reported to have hearing problems. Among 32 who had reported to have hearing problems; 18(56.25%) reported reduction in hearing, 10(31.25 %) reported ringing ear (tinnitus), speech interference and ear infections both account 2(6.25%) of all hearing problems experienced.

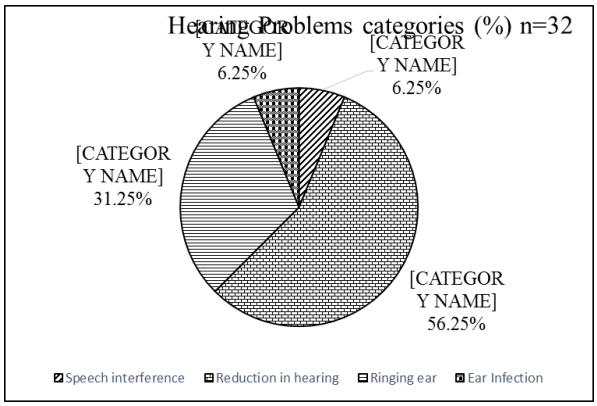

Figure 1: Prevalence of self–reported hearing problems

AUDIOMETRY SCREENING TEST RESULTS AMONG WORKERS IN HEAVY MACHINE MAINTENANCE WORKSHOP

Audiometry results reviewed were for 62(52.1%) workers among 119, the rest 57(47.9%) had not done audiometry screening test. Among 62 workers whose audiometry results were analysed, 60 had normal hearing at baseline taken at employment date, remaining 2 have warning level (i.e. initial stage of NIHL). From the most recent audiometry data (2018 and Jan 2019) only 45(72.6%) had done the periodic audiometry 17(27.4%) had not done any since baseline. Those with recent audiometry, 2(3.2%) had hearing loss that required referral, 8(12.9%) had warning hearing loss and 35(56.5%) had normal hearing.

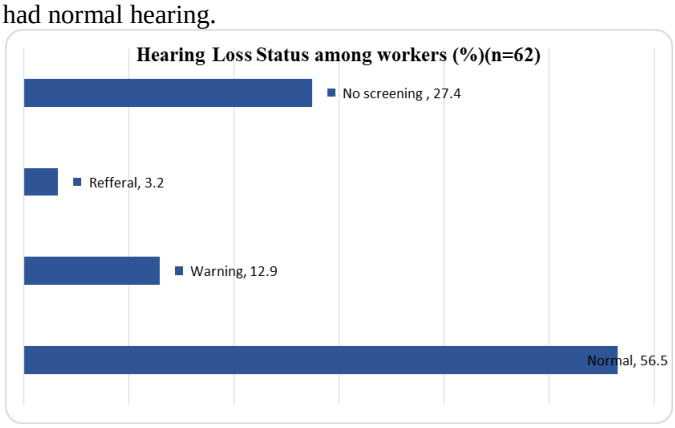

Figure 2: Audiometry screening test results among workers in heavy machine maintenance workshop

LOGISTIC REGRESSION OF RISK FACTORS OF HEARING PROBLEMS AT MAINTENANCE WORKSHOPS

Prediction of hearing problems using identified risk factors of noise levels, ototoxic drug use, organic solvents and exposure duration was done by. A binary logistic regression was conducted for every single factor alone and then adjusted for age. While adjusting for age, duration of work, use of organic solvents at work, and HPD use was found to influence hearing problems (OR>1). Duration of exposure to noise environment COR is significant without adjusting to age.

Variables	Hearing problems n (%)	COR (95%CI)	AOR (95%CI)	p-value
Noise exposure levels				
>85 dB(A)	11(45.8)	1.688(1.58-5.07)	1.71(1.69-1.97)	0.002
<85 dB(A)	19(50.0)	1		
Age (years)				
≤ 35 years	28(40.6)	1		
>35 years	33(66.0)	1.919(1.67-3.97)	2.01(1.981-4.09)	0.005
Duration of exposure (years)				
>10 years	35(67.3)	1.87(1.81-2.96)	1.91(1.86-3.11)	0.009
<10 years	26(38.8)	1		
Organic solvent				
Use	60(56.1)	1.124(1.04-2.22	1.20(1.06-2.23)	0.009
Not use	1(8.3)	1		
Frequencies of using HPD				
Regularly	39(35.1)	1		
Sometimes/rarely	6(75.0)	1.37(1.29-7.340	1.87(1.38-8.98)	0.025

*Adjusted for age; *Significant at p < 0.05. Note: CI = confidence interval; COR = crude odds ratio; AOR= Adjusted odds ratio*

Table 2: Odds ratios predictors of hearing problem predictors. (n=119)

IV. DISCUSSION

NOISE EXPOSURE LEVELS

Mean personal noise levels in TWA scale was 85.68 dB(A) (Range 68.00 dB(A) to 100.01 dB(A)), in which 34(54.8%) of workers in all job sections exceeded the OEL recommended by NIOSH, WHO and OSHA Tanzania. However, the workers in maintenance workshop are working for 12 hours shift that exceed the required standard work time of 8 hours. In that case, noise exposure limits for a 12-hour shift using an exchange rate of 3 dB and limit of 85 dB(A), based on the equal energy rule, is supposed to be 83.24 dB(A) instead of 85 dB(A). Therefore, basing on OEL of 83.24 dB(A) these workers are at risk of developing hearing problems mainly NIHL.

Other studies reported exposure to high levels of noise at workplace (Chadambuka et al, 2013) and (John W et al, 2018) did a study in Tanzania which indicated that workers in maintenance section of gas fired electric plant are exposed to mean noise levels of 89.64 dB(A). A study done to assess prevalence of noise induced hearing loss among employees at a mining industry in Zimbabwe (Musiba Z, 2015) indicated that mean noise exposure levels are for maintenance workers in mining was 103 dB(A). These noise levels are potentially hazardous and might result in hearing impairment among workers in that environment.

Noise levels between different section of workshops was found to differ basing on the job or task performed, in this study (31.4%) of mechanics are exposed to noise of above 85 dB(A), followed by boiler makers and auto electricians with (25.7%) are exposed to noise above 85 dB(A). In a study to review occupational noise exposure and hearing loss in Australia concluded that boilermakers exhibited mean noise exposure of 95.3 dB(A) and almost 100% of boiler makers were exposed to noise levels above 85dB(A) regulatory limit (Cobbet D, 2016). In addition, a noise survey of boiler makers and welders for shipbuilders in India measured noise levels beyond 90 dB(A) (Bhumika N 2016).

Assessment of noise exposure levels of workers in ES and HME workshops indicate that mean 8-hour TWA are 85.04dB(A) and 88.11dB(A) respectively which also are above the required 85 dB(A) OEL, hence we conclude that the workers are highly exposed with noise levels of above OEL.

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PREVALENCE OF HEARING PROBLEMS

Audiometric evaluation of NIHL shows among 62 workers 10 (16.1%) have hearing loss at different levels, in which 8 (12.9%) warning level (moderate hearing loss) and 2 (3.2%) referral level (severe hearing loss). The results of this study indicate the prevalence of NIHL was slightly lower compared with other studies done in Africa. The study done by *Musiba* Z indicated 47% prevalence of NIHL among miners, with 35% mild hearing impairment and 12% poor hearing (Musiba Z, 2015).

When a questionnaire was used the prevalence of self-reported hearing problems was observed to be higher than that from audiometric test i.e 32 (26.9%). The difference between the two assessments could be due to the number that had no audiometry results 74(62.2%). The difference could also be due to the occurrence of the audiometry versus the reported information. This prevalence was lower compared to that reported among gas- fired electric plants, 53.8% (John et al, 2018). The difference could be the due to the different working environment and the age of the workers. Another study reported prevalence of NIHL of 37% among workers in mining industry in Zimbabwe (Chadambuka et al, 2013). A study of on hearing impairment among workers in gold mining in Ghana reported a prevalence of 23% (Amankwa I et al, 2016) which is slightly similar to our study.

The results also reveal that self-reported hearing problem categories were, 18(56.25%) report reduction in hearing, 10(31.25%) ringing ear (tinnitus) and ringing ears and speech interference both scored 2(6.25%). This prevalence is slightly lower than those reported in a South African study among miners where reduction in hearing was 38% and tinnitus 45 % (*Nelson D et a 2016)* who reported that 16% of the disabling hearing loss in adults is contributed to occupational noise, ranging from 7% to 21% in the various regions.

DETERMINANTS OF HEARING PROBLEMS AT HEAVY MACHINE MAINTENANCE WORKSHOP IN MINING SITE

AGE

This study also associated hearing problems with other factors such as age of respondents in which workers within above 35 years have highest prevalence of hearing problems about 33(66.0%), the odds of increasing hearing problems with age was statistically significant at (p= 0.006) as the age increase so do hearing problems. This correspond with the study of (Musiba Z, 2015) which indicate age group of 30-39 have 21% and 6% of developing mild and poor hearing impairment. In a Zimbabwean study (Chadambuka et al, 2013) the prevalence of NIHL among employees at a mining industry was found to increase as a function of age in which 29-39 age group was observed to have 25% NIHL. The South African study reported the youngest age group to be highly affected with NIHL which is different to this study. In another study of Occupational NIHL in auto part factory workers in welding units in Thailand (Sriopas A, 2017) found that workers with > 30 years of age had 86.7% of abnormality in both ears.

DURATION OF NOISE EXPOSURE

Workers with >10 years of employment had higher prevalence of hearing problems 67.3%. This opposed with the study done in Tanzanian mines which indicated that the workers with > 10 years of exposure had 7% prevalence of poor hearing compare to the lower groups. In another study done in Thailand (Sriopas A, 2017) indicate those who are exposed in work environment for >10 years had relative higher 26.7% of developing hearing loss in both ears compare to those with low exposure duration. Nevertheless, this association is not significant compared with the study of prevalence and degree of noise- induced hearing loss in South African gold miners (Satheley E 2015) which showed that 66.7% had no NIHL among those worked 10-15 years this might be due to small sample size used. NIOSH has found that 8% excess risk of developing occupational noise-induced hearing loss during a 40-year lifetime exposure at the 85-dB(A) OEL, this means within prolonged exposure of noise even below 85 dB(A) there is high probability of developing NIHL (NIOSH Guideline).

ORGANIC SOLVENTS USAGE

The very significant result has been observed in the use of organic solvents at the workshops in which 60(56.1%) of people who use organic solvents have reporting experience hearing problems. These results are associated with many previous studies such as, in a small cross-sectional study, (Fuente et al, 2006) reported that solvent exposure is associated with hearing loss. Chang et al. compared hearing capacity in 58 employees with exposure to noise and toluene with 58 employees with noise exposure only and 58 non exposed workers. The prevalence of hearing loss >25 dB was higher in the noise plus toluene group compared to the noise group and lowest in none exposed group. (Kowalska M et al, 2007) reported that the combination of noise and solvents, such as styrene, xylene, n-hexane and toluene, caused a hearing loss in a study of 1117 workers from different industries. Those solvents such as toluene, styrene, xylene, isopropyl alcohol, and ethyl benzene they tend to damage the cochlea (predominantly the supporting and outer hair cells) and provoke irreversible sensorineural hearing loss (Arvel L,2016).

Hence, this study supports the hypothesis that co-exposure to excessive noise and organic solvents at workplace may increase the risk of hearing loss employees are susceptible to such risks (Choi Y et al, 2014).

HEARING PROTECTION DEVICES USAGE

All 119 workers reported using HPD provided, this can be due to the company mandatory HPD use policy, as indicated in the study of Corbett et al which found that the institution of a mandatory hearing protection policy (p = <0.01) was determined to be the most significant positive predictor of self-reported HPD use by study workers (Corbbet D, 2016). However, the use of HPD vary with conditions, 111(93.3%) of workers reported using HPD all the time while working, 8(6.7%) use sometimes depending on circumstances. This

HPD use proportion can be related to the study of (John W et al, 2018) which indicated majority of participants in gas-fired electric plants (95.3%) use hearing protective devices. About 7.5% participants use ear plugs, 38.7% participants use ear muffs and 53.8% participants use both ear plug and ear muff

All time use of HPD (in this case ear plugs) had an indicative relationship with reduced chances of having hearing problems 35% compared to 75% for rare use. A study done among gold miners in Ghana indicated a protective effect with frequent use of earplugs (OR 0.46) (Amankwa I et al, 2016).

The mine safety management provide form earplugs with noise reduction rate (NRR) of 25 dB to all workers, this is the major HPD provided. About 19.3% and 45.4% among workers showed that they are *very satisfied* and slightly *satisfied* respectively, with the type of hearing protection provided while 35.3% are not satisfied with HPD provided.

Moreover 61.3% of workers frequently receive training on effectiveness and awareness of PPE use and safe work practices, this result is similar with the findings of John et al who report about 85(80.2) participants had training on the hearing protective devices. In another study done to evaluate occupational noise exposure and hearing defects among sawmill workers in Thailand a smaller number of workers (25.0%) had received training in proper use of PPE and half of them reported never or only rarely wearing PPE while working (Phayong T et al 2018).

V. CONCLUSION

Findings from this study indicate that personal noise exposure levels for maintenance workshop workers at gold mine site in Tanzania were above required occupational exposure limits by WHO, NIOSH and OSHA Tanzania. Prevalent self-reported hearing problems facing workers in heavy machine maintenance workshops include reduction in hearing, ringing ear (tinnitus), speech interference and ear Infection. The use of organic solvents, exposure duration and prolonged twelve-hour work shift may have influence on noise exposure levels and hearing status of workers. Besides being provided with HPD and mine safety regulations (mandatory HPD usage policy) there were workers who did not use HPDs as required. Hence the issue of satisfaction with HPD may be of importance to adherence usage.

ETHICAL APPROVAL

The ethical clearance for conducting this research was granted from Muhimbili University of Health and Allied Sciences (MUHAS) research and publications' Ethical Review Committee with reference number DA.287/298/01A. An introduction and permission request letter was sent to mine manager prior to commence of data collection. Confidentiality of the respondents was ensured at all stages of the study.

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