Assessment of noise levels in heavy and light industries in Blantyre City, Malawi

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Abstract

This study was aimed at assessing noise levels in various companies in Blantyre City, Malawi in relation to their compliance with the National Standards and the Occupational Safety, Health and Welfare Act of Malawi (1997) on noise pollution control program. The noise levels, ambient temperature and humidity were measured in various sections of the different industries in the city. A questionnaire was used to check if the industries applied any control measures to prevent induced hearing loss. The results show that noise levels in most industries are above the recommended limit level of 85 dBA. The study has also shown that only 21 % of the industries complied with the national regulations. Lack of noise data, awareness, commitment, and enforcement by the regulatory authorities were observed to be contributing factors to the failure to implement induced noise hearing loss control programmes. The study recommends that in some sections of the industries where the noise levels are high, programs to reduce or prevent hearing loss should be implemented. In addition, there is a need for regular inspections of noise levels in industries out to ensure compliance of permissible noise levels.

Key words: *Compliance, Decibels, Hearing loss, Industries, Noise levels.*

1.0 Introduction

Industries in developing countries such as Malawi, despite bringing in a lot of developmental activities, can also be associated with several adverse effects on the environment and the health of the workers. The activities carried out by most of the industries include, but not limited to, construction of roads and buildings, production of textiles, food processing, production of agro-chemicals and automobile parts. However, processing and production machinery and equipment produce excessive noise that is a health hazard. Noise has been defined as any unwanted or damaging sound (Government of Malawi, 2005a; Government of Malawi, 2005b, Government of Malawi, 1997). This noise has been observed to cause temporary and permanent hearing loss and psychological effects such as annoyance, stress, hypersensitivity to sound, increased blood pressure and heart rate, difficulties in breathing and increased sweating that may result in nausea and fatigue (Cohen et al., 1980; Thompson, 1996; Melamed, 2001). Noise can also interfere with communication leading to errors and failure to respond to warning signals (Moudon, 2009; Shridhar, 2009). Shridhar (2009) observed that noise induced hearing loss appears to be a dominant factor for listeners of less than 69 years of age whereas aging (presbyacusis) appears to be a dominant factor for age greater than 70 years. Prasher (2003) reported that the age of 55 years is used as a limit for an onset of detectable age induced hearing loss.

It is estimated that there are over 120 million persons with disabling hearing difficulties worldwide (Bhattacharya, 1981; Smith, 19980, 0Yeun, 2004). Furthermore, studies in the United States (US) have shown that about 30 million workers are exposed to noise in their work place and that the noise accounts for 30% of all acquired hearing loss of the US population (Smith, 1998). Boateng and Amedofu (2004) described a work place as an important part of human environment and that the protection of health and safety of the workforce from hazards related to work activities is very important as it forms the basis for a healthy and vibrant economy of a country. Similarly with the growing economy of Malawi, it is estimated that there are many industries that produce noise levels in excess of 85 dBA, a value that is the recommended threshold limit as stipulated in Malawi Standard and OSHAW Act (Government of Malawi, 2005b; Boateng and Amedofu, 2004). Subramanian et al. (2004) indicated that the society is now aware that high noise levels can damage hearing. However, it has also been argued that because noise produces no immediate effects on the public, the public has been largely uninterested in its suppression. It is for such reasons that most African countries set up regulations that limit noise exposure to industrial workers (Subramanian et al., 2004). Malawi also enacted laws (Government of Malawi, 1997) and published Malawi Standards (Government of Malawi, 2005b) to guide industries to institute noise induced hearing loss abatement programs. The extent of compliance to these laws and Standards by industries in Malawi is not known and it is for this reason that this study was carried out.

2.0 Methods

This section describes the sampling method used to determine the companies where the study was carried, the experimental method used to determine the noise levels and the method used to check for compliance with the Malawi laws and standards on permissible noise levels.

2.1 Sampling of companies

A purposive sampling method was used to select companies that have machines and equipment that generate noise. Determination of the industries that produce noise equal or above the limit of 85 dBA was based on the results obtained by a spot/visual check and audio sensory noise survey that was carried out in industries by the Occupational Safety and Health Department of the Malawi Government. Any industry found to contain sound levels equal or above 85dBA per 8 hour period per any day was considered a sample containing a noise hazardous area as stipulated by Malawi Standards (Government of Malawi, 2005b). Using this procedure, a sample size of 40 industries was identified and categorized into 13 strata based on their homogeneity and characteristics of work. A total of 21 industries from 13 strata were sampled using a stratified sampling method. The 13 strata were: Textile industry, Food and Grain milling industry, Iron and Steel industry, Wood industry, Tobacco industry, Bottling industry, Plastic industry, Packaging industry, Polyethylene Terephthalate (PET) Plant industry, Tissue industry, Confectionery, Fertilizer and Printing industry. To determine the sample size (*S*) from each stratum, proportional representation was obtained using:

$$S = \frac{P}{N} * n \tag{1}$$

where S = sample size in each strata; N = total number industries in a cluster; P is the number of industries in each strata and n is the number of samples for study in this case, 21 industries. The result from (1) was then rounded off to a whole number. The other samples from each stratum were selected randomly, except for two cases where the stratum had one company that was selected without option.

Experimental method

From the companies sampled, noise levels were measured using Integrated Sound Level Meter (ISLM) and a thermo-hygrometer was used to measure weather conditions. The ISLM was chosen because it contains a suitable statistic averaging technique, capable of yielding a concise measure of equivalent continuous sound pressure level (Leq). Prior to carrying out any noise measurements, the status of the power battery for the sound level meter was checked and the meter was calibrated using castle acoustic calibrator (model is GA 601). The calibration was carried out according to the instrument operational manual provided by the manufacturer (Castle Group Ltd, 20140).

The ISLM used has four available frequency-time weighting choices of *A* for slow or *C* for fast. Fast and slow are the response times of 0.125 seconds and 1 seconds respectively, over which the instrument averages the sound level before displaying it on the readout. In this, study, “A fast” scale was chosen as recommended by other international standards (0International Organization of Standardization (ISO), 1995). This is because it is a frequency- time weighting network which mimics responses of the human ear and it has been incorporated in many Occupational Noise Standards (0National Institute for Occupational Safety and Health, 1998). The *A* weighting network has also been recommended to be more reliable when associated with people’s reaction for many applications (Ismail et al., 2009). The ISLM has three working ranges of 35-100 dBA, 55-120 dBA, and 75-140 dBA. However, the working range of 55-120 dBA was chosen because most noise level readings fall within this range (Castle Group Ltd, 2014) and partly because the targeted noise level was 85 dBA.

Identification of the sound source was done by visual and audio inspections and also by measuring the sound using the ISLM. The measurement of the noise was done by hand, holding the instrument at 1.2 m above the ground and 3 m away from the source while pointing the microphone towards the front of the main source of noise to be measured as recommended by Castle Group Ltd (2014). The recommended height and the distance used during measurement are such as to minimize the interference of the sound field. Any noise level equal to or above 85 dBA standard limit is important for initiating a hearing loss control program, and it is for this reason that it was targeted for noise exposure measurement at a work station. However, in cases where sound levels were below 85 dBA, the period of exposure was a determinant for taking measurements. This is because when the period of exposure is increased from 8 hour period, the impact on the noise hearing loss also increases. Thus the limit levels when normalized per 8 hour period would be lower than 85 dBA. The statistical formula used to find the normalized Equivalent Sound Level of an 8 hour noise exposure (LAeq) is given by:

$$LAeq,8hr = Leq(T) + 10\log_{10}(T/8) \tag{2}$$

where *T* = the shift duration of exposure in hours.

Once the source of the noise above the recommended limit was identified, the next step was to measure the noise at the work station affected by that noise. Noise exposure levels were measured at the position of employees close from the entrance of the external ear canal (sound receptor) at a distance of about 0.10 ± 0.01 m as recommended by the ISO (1995) and National Standard (Government of Malawi, 2005b). The measurements were carried out at each employee while he/she kept his/her work posture. The equipment was set to give readings in decibels (dBA) “fast” frequency and time weightings which mimics the responses of the human ear. The sound level readings (dBA) were then recorded every 10 seconds and up to 50 readings for every work station. This was carried out in order to get a better representation of the averaged sound level variations and the sound level for an extrapolated 8 hour period.

After every 50^{th} reading of the sound level, the equivalent continuous sound level in dBA (Leq) was obtained from the ISLM. Leq was more concise and an important statistical descriptor that represents the logarithmic average equivalent continuous sound pressure (dBA) level which has the same energy as the original fluctuating noise for the same given sampling period of time at a speed of 125 milliseconds per reading. The Leq was superior and concise to the readings observed at every 10 seconds interval since these readings could miss out other important higher or lower readings.
In addition to the sound level recordings, temperature and relative humidity were also recorded using a Thermo-Hygrometer to determine physical weather conditions to ensure that the instrument operated within the recommended ambient temperature (from -10 ^{o}C to +50 ^{o}C) and relative humidity (from 25 to 90 %) (Castle Group Ltd, 2014). This is because any reading outside this range would affect the correctness of the results. The effect of wind was negligible as the noise measurements were carried out indoors.

Determination of the exposure time of workers to the various noise levels was determined by recording the period a worker was exposed to the noise above the limit, at the work station in a day. The record of time in hours per day for the workers was obtained from the supervisor through enquiry, and through the time sheet that indicated the period each worker kept their working posture at the work station. Tea breaks, lunch breaks and knocking off periods were subtracted from the given time of entry. The remaining time was considered an estimate of the time the worker was fixed at the work station. The calculation of real sound level exposure was done using normalized total daily exposure levels using equation (2).

The daily noise exposure in individual industry may consist of periods of different noise levels and different sections of different noise levels. It is for this reason that daily dose was computed so that comparisons could be made between sections within a company and also between companies. Dose is the amount of actual exposure relative to the amount of allowable exposure and for which 100 % and above represents exposures that are hazardous. The Noise Dose was calculated as (Government of Canada, 2004):

$$\text{Noise dose (D)} = \left(\sum_1^n \frac{C_i}{T_i} \right) x100 \qquad (3)$$

where C_n is the total time of exposure at specified noise level and T_n is the exposure time at which noise for this level becomes hazardous.

Thus the Dose % helps to compare the degree of hazard risks within widely varying noise exposure levels in different sections of a company. Determination of the number of workers exposed to hazardous noise levels was done by physically counting the workers affected by the noise in their work stations and also by using attendance registers for the months.

2.2 Verification of Compliance

Verification of compliance with National Standards and the Occupational Safety, Health and Welfare Act on noise pollution control program was done by observing the actions taken by both the employers and the employees in respect to the available noise level, and then comparing them to the minimum requirements that are supposed to be adhered to in order to control hearing loss as stipulated in the International and National Standards. The second way of verifying compliance was by using a questionnaire that was administered to Health and Safety officer of the company.

3.0 Results

Table 1 shows variations of the noise levels in different categories of the industries. The Table shows that the noise levels are well above the safety limit of 85 dBA in most of the industries and hence most of the companies. This data also shows that most of the workers in these industries are exposed to these high noise levels for long periods.

Table 1: Summary of noise measurement results

Industry	**Leq (dBA) Range Normalised**	**Dose % Range**	**No. of People Exposed**	**Total no. of people**	**% of people exposed**	**Duration of exposure (Hrs)**
Fertiliser	89.9-102	300-6000	18	100	18	11
Milling	85.5-98.5	150-2500	53	750	7	8-11
Wood	86.6-98.7	150-2500	42	400	10.5	8
Packaging	75.3-96.7	<20-1500	88	250	35.2	8
Tobacco	86.1-94.5	130-900	128	1800	7.1	10
Printing	74.5-92.9	<20-600	136	400	34	8-12
Steel	91.5-92.4	450-550	6	20	30	8
Textile	83.1-91.6	60-450	112	250	44.8	11-11.5
Bottling	86.5-91.3	140-400	7	125	5.6	2.7-8
PET Plant	85.7-90.4	120-350	10	25	40	8
Toilet Tissue	89.7	300	3	25	12	8
Confectionary	85.5-86.5	110-140	18	600	3	7.75
Plastic	77.9-81	20-40	0	196	0	14

Figure 1 shows the noise levels in various categories of the industries. The highest Leq dBA measurement was found in the fertilizer industry with a reading of 102 dBA. This is seconded by Milling and Wood industries with values of noise level Leq of 98.5 dBA and 98.7 dBA, respectively. The lowest Leq dBA range was observed in plastic industry with the highest Leq average of 81 dBA. The Malawi Standards of noise acceptable noise levels stipulates that the threshold limit level of noise is 85 dBA and Dose of 100 %. Thus most of the industries in Blantyre city of Malawi have noise levels that are above the allowable limit.

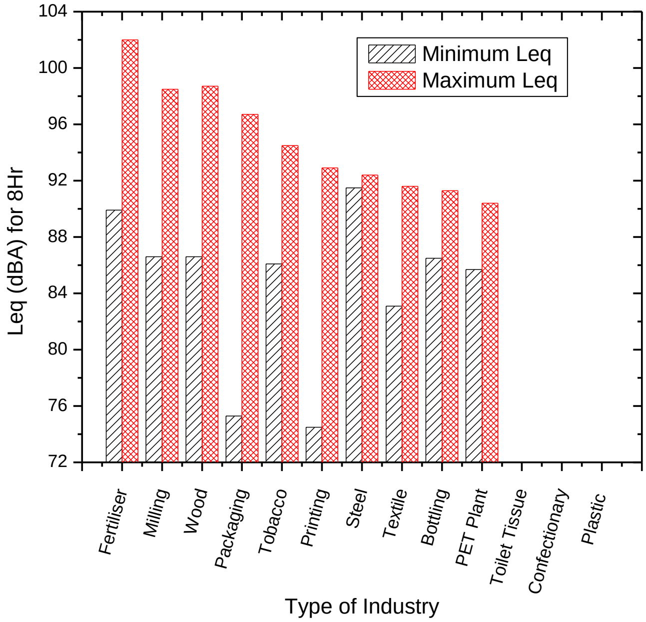

Figure 1: Noise level in the industries, Blantyre city

Since the impact of the noise levels on the workers depends also on the duration of which the workers are exposed to the noise, a Dose % that takes into account the duration of exposure was computed. Figure 2 shows the Dose % of noise for various industries in the city of Blantyre, Malawi. The Fertilizer industry has the largest maximum Dose % (6000 %) and this is seconded by the Milling and wood industries with a maximum Dose % of 2500 %. The lowest Dose % was observed in plastic industry with maximum dose of 40 %. The low maximum Dose % observed in the plastic industry is because the plastic industry is using modern machinery designed to produce less noise.

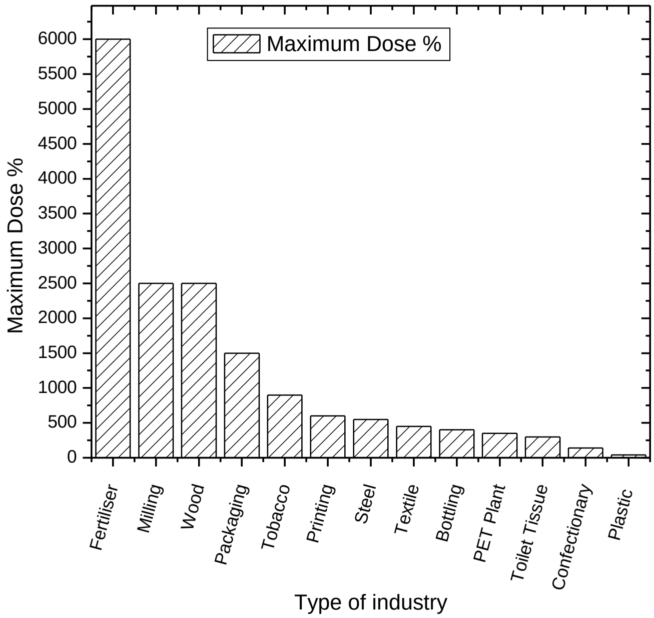

Figure 2: Maximum Dose % per Industry

The effect of noise produced in any company can be worse if the number of workers that are exposed to it are many and if they are also exposed for long periods. Figure 3 shows the Leq noise levels and the number of workers exposed to the noise for the various industries. Plot (a) of the figure shows that for industries that have minimum Leq noise levels above the allowable limit of 85 dBA, they have significant percentage (over 30 %) of the workers exposed to these high noise levels. These industries are the Fertilizer, milling, wood, tobacco, steel, bottling, and PET plant industries. In plot (b), a significant percentage of the workers are exposed to high levels of noise that are above the recommended limit.

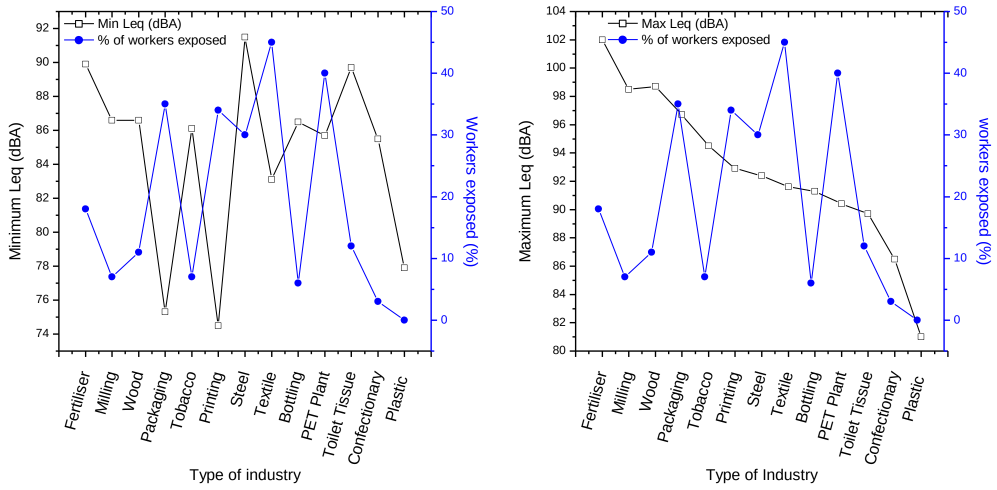

Figure 3: Number of workers exposed to various noise levels

The highest number of workers exposed to hazardous noise level was in the printing industry. The lowest number was in toilet tissue making industry with leq 89.7dBA and a dose of 300 %. However the highest risk of hearing loss was found in fertiliser company with 18 % of the workers (Figure 3) exposed to Leq 102 dBA that had a dosage of 6000 % (Figure 2).

The total number of workers in the sampled companies was 4941 and a total of 621 was exposed to high levels of noise. Thus 12.6 % of the workers were exposed to high levels of noise. Figure 4 shows the number of workers that were exposed to high noise levels that were protected. Only 4 Industry categories , namely Tobacco, PET plant, Bottling and Milling industries had their workers protected. Thus out of 12 categories of industries, only 4 categories (representing 33.3%) are able to protect their workers against hardous noise levels. Thus a large percentage of the industries are not able to comply with the International and National Standards on noise levels.

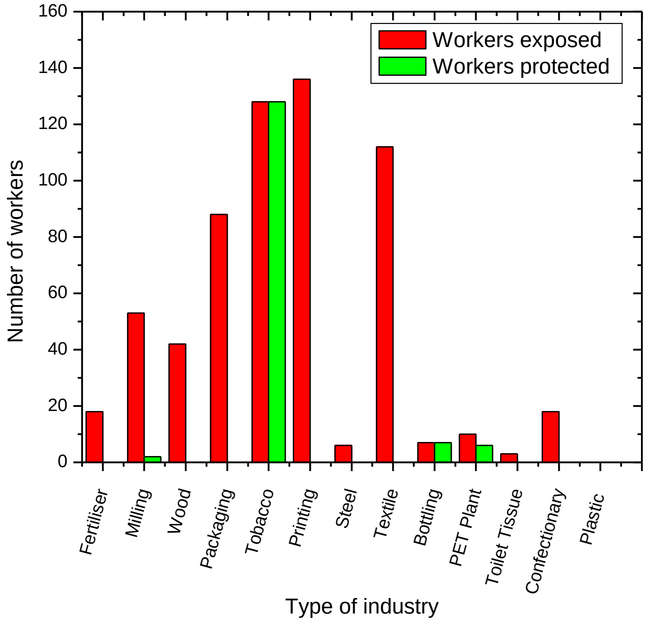

Figure 4: Workers exposed and protected

Figure 5 shows that out of the 621 workers that were exposed to noise, only 143 (23 %) workers were protected by reducing time of shifts, providing Personal Protective Equipment (PPE)s and by separating the workers from noise machines. About 77 % of the workers were not protected. The higher number of workers exposed to hazardous noise without protection is an indication that a large number of workers were at risk of noise induced hearing loss.

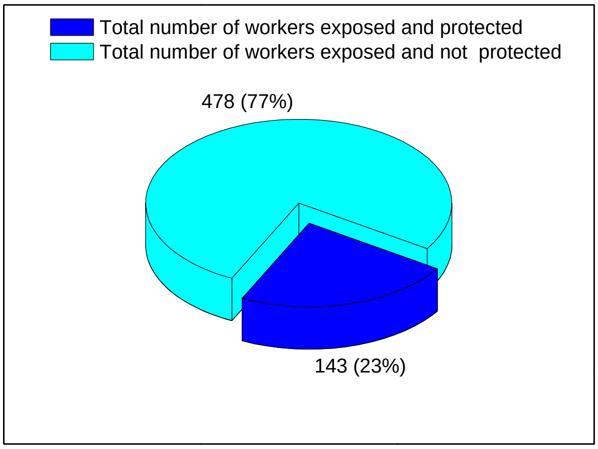

Figure 5: Percentage of workers exposed to high noise that are protected and not protected

Figure 6 shows the percentage of workers exposed to hazardous noise in each industry as percent against total number in each industry. The results indicate that the highest percent was in printing industry (22 %) seconded by Tobacco industry (21 %). This implies that though there are high noise levels in the fertilizer industries, the percentage of the workers exposed to the high noise levels is minimised.

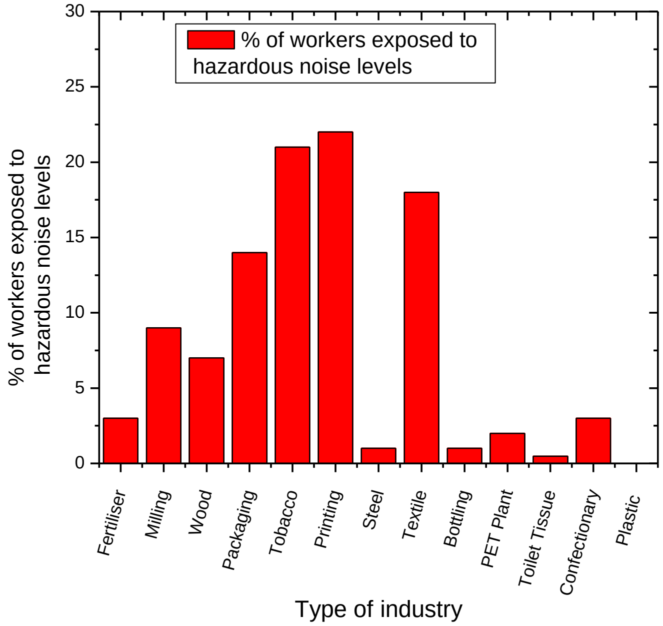

Figure 6: Percentage of workers exposed to hazardous noise levels

3.1 Compliance with National Standards and the Occupational Safety, Health and Welfare Act on noise pollution control program

The questionnaire was administered to all 19 industries studied in order to verify the actions taken by industries in relation to the measurement of the noise level results which were observed to be equal or above the threshold of 85 dBA. **Error! Reference source not found.** provides a summary of results obtained from the questionnaire. A 'Yes' in the table indicates the industry which implemented the action required while 'No' implies the industry did not implement the action required. Two industries (Plastic and Printing) did not qualify for compliance check since the noise levels were below the threshold level of 85 dBA and therefore deemed not to pose any threat of work induced hearing loss. The table shows that out of 19 industries studied, 42 % had a hearing loss control program and noise standards available in their industries. The table further indicates that 21 % of the same industries that had noise assessment and monitoring programs also implemented the hearing loss control program. Noise assessment and monitoring have an important role in industry in order to continuously identify the workers affected and determine the extent of the noise problem. This exercise would further help the industries to come up with proper hearing loss prevention measures.

Table 2: Questionnaire Summary

Requirement	***YES**	**NO**
1.1 Hearing Loss Control Program	8	11
1.2 Standard used	8	11
1.3 Exposure Assess	4	15
1.4 Noise monitoring	4	15
1.5 Own Equipment	1	18
1.6 Calibration	1	18
2.1 PPEs	8	11
2.2 PPEs Rating	3	16
2.3 Audiometric Test	3	16
2.4 Medical Surv. Test	3	16
2.5 Exit audiogram	3	16
3.1 Warning Signs	4	15
3.2 Hearing Loss Awareness	6	13
3.3 Training Prog	3	16
3.4 Evaluation Prog.	3	16
4.1.1 Exp Ass. Records	4	15
4.1.2 Med. Surv. Rec.	3	16
4.1.3 Training Records	3	16
4.1.4 Hearing Prot. Rec.	4	15
4.1.5 Minutes of Review Meetings	3	16
4.2 Access to Records	4	15
4.3 Visits by Inspectors	3	16
5.1 Noise control Program Important	19	0
5.2 Awareness on existing Regulations	11	8

***Yes** indicates the number of industries which implemented the action required while **No** implies the number of industries which did not implement the action required)

Error! Reference source not found. also shows that 5 % of the industries owned the measuring equipment for sound levels while 95 % did not own it. Measurement of noise is an important tool to give base line information on the levels of noise and be able to determine the appropriate control measures. These employees are required to be enrolled on hearing conservation programs either by providing personal protective equipment (PPE) such as plugs, muff, and canal cup or reducing their duration of noise exposure. Furthermore, these workers should also be subjected to audiometric and medical surveillance tests. The table shows that 42 % of industries were able to provide PPEs against 58 % who were not able to provide the PPEs to their workers.

This study also revealed that only 16 % of the industries used the correct classification of PPEs based on the noise data available in the industry, whereas 84 % did not. The other requirement of compliance is to place warning signs indicating hazardous noise areas. This study has shown that only 21 % of the industries were able to put warning signs to alert the workers and other personnel found in the areas about the presence of hazardous noise. Warning signs help workers to take precautionary measures before working in the area. Awareness is an important tool for the workers to know about the effect of noise on their health; therefore, industries are obliged to conduct awareness training in their work place.

Error! Reference source not found. reveals that 32 % of the industries studied had established hearing loss control program and had hearing loss awareness program. However, only 16 % of the industries conducted professional training to their staff to manage hearing loss. Evaluation of the program is important to check if the goals of the program are achieved or not. This study has shown that only 16 % of the industries had evaluation program in place while 84 % did not have the program. This means that a large number of employees exposed to noise above or equal to 85 dBA were at risk of not knowing whether the noise control program was effective or not. While some industries attempted to institute a hearing loss control program only 21 % of the industries managed to keep records on noise test data, noise evaluation and assessment and medical surveillance. The records are important because they serve as medico-legal evidence in case of workman's compensation and also they act as a base line for comparison during evaluation.

21 % of industries studied had records that could be accessible to an employee and any client (medical personnel, legal entity etc) who would wish to use the data as per requirement of the hearing loss control program. The study also showed that only 16 % of the 19 industries were visited by occupational safety and health inspectors on noise regulation program. The inspectors that visited them were private inspectors hired to oversee that all the Quality Systems in the industry were being implemented. Responses from the administered questionnaire also indicated that no public inspectors ever visited the industries, an indication that there was lack of law enforcement by the public officers as required by Occupational Safety and Health Act on Noise.

Error! Reference source not found. also shows that 58 % of industries were aware of the existing standards and regulations on hearing conservation program whereas 42 % were not aware. This suggests that lack of awareness campaigns by the Regulatory Authority must have contributed to a large number of industries not complying with the regulation requirements other than lack of enforcement. However, despite many industries failing to comply with the regulations, 100 %

agreed that Noise abatement program in areas where there is hazardous noise was very important in order to protect the workers from ill effects.

Figure 7 shows the industries complying with the National Standards and the Occupational Safety, Health and Welfare Act on noise pollution control program. Four industries (24%) against seventeen industries which qualified for compliance check, had noise levels above 85 dBA and complied with the minimum requirements of hearing conservation program. These industries were able to provide protection to the workers from noise induced hearing loss by either providing them with PPEs, by reducing period of exposure or separating the workers from noisy machines through working in enclosed control room. The results also show that 13 industries (76 %) failed to comply with the National Standards and Regulations. The 13 industries that failed to comply with the minimum noise standard requirements of providing earplugs to prevent or reduce noise induced hearing loss cited lack of enforcement of the requirements as the major problem. Other industries provided unclassified ear plugs and had no noise data making it difficult to deduce whether the workers were really protected or not. Furthermore, during the survey, most of the workers were observed not wearing the earplugs despite owning them and this suggested that there was lack of awareness and knowledge about the ill effects of hazardous noise. Figure 7 also suggests that there was some kind of relationship between availability of noise data and compliance. The industries with the noise data were able to comply with the National Standards requirement while those without the noise data failed to comply even though some were aware of the regulations. This suggests that availability of noise data plays an important role in informing the industry managers of the presence of noise hazards. Lack of enforcement by the regulating authority also contributed to the failure of complying with the existing standards and regulations.

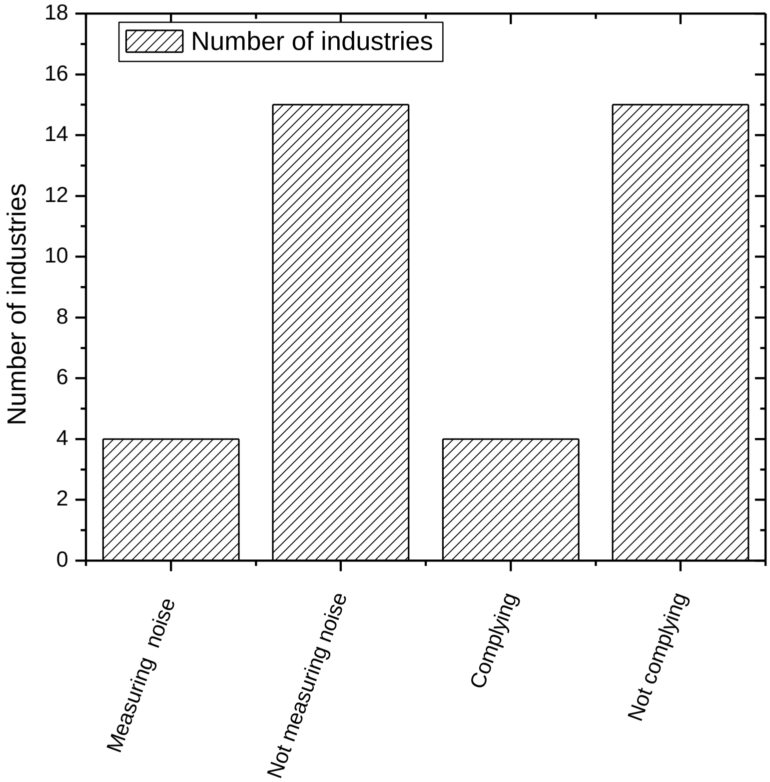

Figure 7: Industries complying with National Standards and the Occupational Safety, Health and Welfare Act on noise pollution control program

The results from this study on noise levels and workers' exposure to noise are comparable to those reported in other studies. Studies by Sataloff et al. (1984) on occupational hearing loss among workers indicated that there is still ignorance among the majority of people working in industries in developing countries about adverse effects of exposure to hazardous noise levels as indicated by failure to comply with the regulations. In Africa, studies on noise levels in saw mills (wood Industry), corn mills and printing industry indicated that 23 %, 20 %, and 7.9 % workers respectively, had evidence of noise induced hearing loss as a result of noise levels above the threshold limit of 85 dBA (Samangwa, 2009). In developed countries, Bedi (2006) also observed high levels of noise in similar industries as those studied in Malawi and this suggests that workers in these industries are also at high risk of noise induced hearing loss. Several authors have observed that for such workers, suitable hearing protection program is a must (Yeun, 2004; Unlu et al., 2014).

4.0 Conclusions

The study has shown that the industries in Blantyre city - Malawi, produced noise levels ranging from 75 dBA to 102 dBA and that many industries are not complying with the National Laws on noise in work places. The study has also shown that 13 % of workers in industries have high chances of suffering from hearing impairment. The results have also shown that 76 % of industries do not comply with the regulations and that law enforcers rarely monitor the industries' compliance. In many industries, noise assessment, periodic monitoring, audiometric medical tests, records keeping, training, awareness programs and warning signs in noisy areas are not practised. It has been observed that despite some workers receiving personal protective equipment (PPEs), few workers used them and this further suggests ignorance of the effects of noise on their health. Training and awareness workshops should therefore be conducted in industries to ensure that each worker understands the health effects of high noise levels.

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