ORIGINAL ARTICLE

ACOUSTIC COMFORT IN INDUSTRIAL OFFICE: A PRELIMINARY STUDY AT A MANUFACTURING COMPANY IN MALAYSIA

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ABSTRACT

Acoustics issues such as noise in the workplace remains one of the most prevalence occupational hazard especially in the manufacturing industry with heavy machineries. Increasing mechanization in all industries and most trades has since proliferated the noise problem. In Malaysia, much has been studied and is known about the auditory effects of noise. However less attention has been given to the non-auditory effects of noise such as annoyance, stress, and work performance, and concern about such effects is a relatively recent phenomenon. In view of this, this study aims to determine the level of noise from different type of machines and tools in a manufacturing plant and also the effects of noise to the employees. A structured questionnaire was used to assess the effects of noise on the workers and sound level meter was used to measure the noise level at selected work areas. The results of this study showed that nearly all the identified work areas exceeded the action level of 85 dB(A) and four of these areas noise levels' are more than 90 dB(A) which is the permissible exposure limit according to the Factories and Machinery (Noise Exposure) Regulations 1989. For the questionnaire, it was found that annoyance topped the noise effects list with 51.4%, followed by stress with 40.0%, hearing deterioration (14.3%) and job performance deterioration (2.9%). As a conclusion, noise control or preventive measures are suggested in order to minimize the health risks from noise exposure.

Keywords: *non-auditory effects, occupational noise, noise level, manufacturing industry; industrial worker*

INTRODUCTION

We heard different sounds every single day in our life and are exposed to the sound without knowing the consequences of the prolonged exposures. Sound and noise are physically the same, differences arising in their acoustic quality as perceived by listeners. This leads to a definition of noise as unwanted and objectionable sound, loud or quiet[1]. Noise can disturb the sensitivity and mental state of an individual, be it by creating negative emotions, annoyance, affecting sleep periods, task performance, social attitudes and health[1].

Noise is one of the hazards faced by workers. Hearing deterioration is the main prevalence of the auditory effects of noise, while the rest are the non-auditory effects of noise. The non-auditory effects on workers' conditions are well known, especially in terms of deteriorating the health of the workers due to physical and psychological stress, annoyance, or noise-induced hearing loss (NIHL)[2]. Other than that, it is also closely related to the work performance, or workers' productivity[2] as noise often disturbs the execution of tasks that required attention and critical thinking, and interfere with communication. Moreover, it contributes to increasing the risks of accidents and injuries.

Manufacturing processes generate noise as an unwanted but by-product of their output with more than 70% of noise exposure occurring in the manufacturing industries[3]. Therefore, noise issue is something that need to be taken seriously especially in manufacturing industry. Factory operators that work long hours were exposed to the annoyance and accident risks at workplace. Therefore, the level of industrial noise and its effects to workers can't be taken lightly. Because of that, this study is conducted to investigate the seriousness of industrial noise effects to industrial workers.

Various studies regarding noise effects to industrial workers had been done in the Malaysian industry. However, to the best of our knowledge, most of the researches are concentrated on noise induced hearing loss (NIHL). As hearing loss is the major effects of noise exposure in the industry, it is understandable that the topic is vastly covered by many researchers. The relationship between hearing impairment and excessive occupational noise exposure has been well established and unquestionable[4, 5, 6].

In terms of the non-auditory effects of noise, the topic, on the other hand, is not as widely researched as hearing loss because only noise associated with hearing loss was identified as an occupational health risk factor by WHO[7]. Previous studies found that there was a strong relationship between industrial noise levels and percentage of highly annoyed respondents[8]. Annoyance is the most widespread subjective response to noise[9], while disturbance from noise will indirectly cause stress and decreasing work performance.

Noise also influenced the work performance, depending on the type of tasks being performed. Listening task obtained large decrement of performance while being exposed to high level noise, or working in quiet environment. However, there is no performance decrement in visual-attention task[10].

In Malaysia, research related to the non-auditory effects of noise to industrial workers had not been given due emphasized. To ensure the health and safety of the workers who are exposed to excessive noise, the Malaysian government had introduced the Factories and Machinery (Noise Exposure) Regulations in 1989[11].

Hence, the objective of this study is to understand the opinion of the employees at a manufacturing plant regarding the noise level and the impact of noise, both auditory and non-auditory, through social survey. Furthermore, the noise level of the machines will be measured to determine the noise emission of the workplace.

METHODS

Workplace Description

The study was done in a local manufacturing facility located in Subang Jaya, Selangor, Malaysia, providing flow equipment products, systems and services to worldwide oil, gas and process industries. With fourteen CNC machine tools, two stick welders, one TIG welder, blast and paint booth available here, these machines created loud noises.

Perception of non-auditory effects of noise

There are 70% workshop employees at this facility, with 95% of them male. This study focused on 35 male workers who were exposed to noise level up to 8 hours per day.

A questionnaire was used to determine the respondents' noise level perception, and the effects of noise on hearing, annoyance, stress and job performance. Cronbach's alpha or coefficient of internal consistency is used to test the reliability of the questionnaires with multiple semantic scales, also known as Likert scales. The higher the value of α is nearing to 1, the higher the reliability. α value that is less than 0.6 indicates a low reliability, while values above 0.7 shows good reliability[12.] The Cronbach's α value for the questionnaire is 0.82 which indicated a high reliability.

The questionnaires was distributed by hand and completed by the 35 selected workers themselves. The purpose to perform the survey is to analyze the noise perception level of workers and the effects of noise during working hours.

Noise measurement

The (A) weighted sound pressure level was measured by a Type 1 sound level meter (SLM), the ONO SOKKI wide range precision (LA-5560). The SLM was positioned at a height of 1.2 meter above the ground. A diffuse field microphone was connected to the SLM. The noise measuring system is then placed in the center of the workplace and far from any reflecting surface. This distance of the measuring system is within the near field area. The near field area is the area very close to the machine where the sound pressure level may vary significantly with a small change in position. This means that the measured noise level is more or less equal to the level heard by the workers.

The seven stations as follows that was identified for noise measurement in the facility are located near the main sound sources: machine shop, weld shop, deburr and stamp area, painting and blasting booth, packing area (boxing activity), testing and assembly, and compressor area. Since sound level meter provide a measure of sound intensity at only one point in time, it is necessary to take a number of measurements to estimate noise exposure over a workday. Even the noise level value of one machine is different when measured at different stations around the machines. Therefore, measurements were repeated three times at the surroundings of the machines (front, left and right), and the average value was calculated to ensure precise measurement and represent the noise level of the machine.

The measurements will be categorised to three stages as indicated in the Factories and Machinery (Noise Exposure) Regulations (1989): (i) less than 85 dB, (ii) 85 to 90 dB (action level), and (iii) more than 90 dB (permissible exposure limit) order to verify the results from the questionnaires.

Calculation of the total sound pressure level (Total Sound Pressure Level) and total permissible duration of exposure for the 7 areas of work can be done using a logarithmic formula as follows:

$$\mathbf{SPL_{tot} = 10 \log_{10} \Sigma 10^{0.1 SPL_i} \ (dB)}$$

Note:

SPL_{tot} - Total sound pressure level from multiple sources

SPL_i - Sound pressure level from source *i* (dB(A))

RESULTS

The results of this study is separated into two parts, the noise level perception and noise measurements. In the results obtained from the questionnaire given to 35 workers, the subjects clearly states that they are experiencing high levels of noise in their workplace. The second part of the results is the noise measurement in the working areas, which shows that there are work areas with noise levels that exceed the Action Level.

Social survey – Noise Level Perception

Table 1 below explained the respondents' demographic profile that consists of department, job designation, gender, age, race, marital status, academic qualification and working experience.

Table 1 - Frequency statistics for demographic variables

Variables		Frequency	Percentage (%)
1. **Department**	Machine shop	20	57.1
	Weld shop	4	11.4
	Deburr & stamp	3	8.6
	Painting & blasting	3	8.6
	Packing	2	5.7
	Testing & assembly	3	8.6
2. **Job Designation**	Management	0	0.0
	Executive	0	0.0
	Non-Executive	35	100.0
3. **Gender**	Male	35	100.0
	Female	0	0.0
4. **Age**	Less than 18 year old	0	0.0
	19 – 35 years old	24	68.6
	36 – 55 years old	11	31.4
	56 years old and above	0	0.0
5. **Race**	Malay	25	71.4
	Chinese	0	0.0
	Indian	7	20.0
	Others	3	8.6
6. **Marital Status**	Single	8	22.9
	Married	27	77.1
7. **Academic Qualification**	PMR	0	0.0
	SPM	11	31.4
	STPM	0	0.0
	Diploma/Degree	21	60.0
	Others	3	8.6
8. **Working Experience**	Less than 1 year	3	8.6
	1 – 3 years	6	17.1
	5 - 10 years	19	54.3
	More than 10 years	7	20.0

A five step semantic scale (1 – Very Low, 2– Low, 3– Moderate, 4 – High and 5 – Extremely High) was used to find out the perceptions of noise levels by the respondents.

46% of the respondents agreed that their work areas have 'high' levels of noise while 9% felt that the noise level is extremely high. 40% felt that the noise level is moderate or tolerable. And only 6% felt that their work areas have low level of noise. The results is shown in Figure 1.

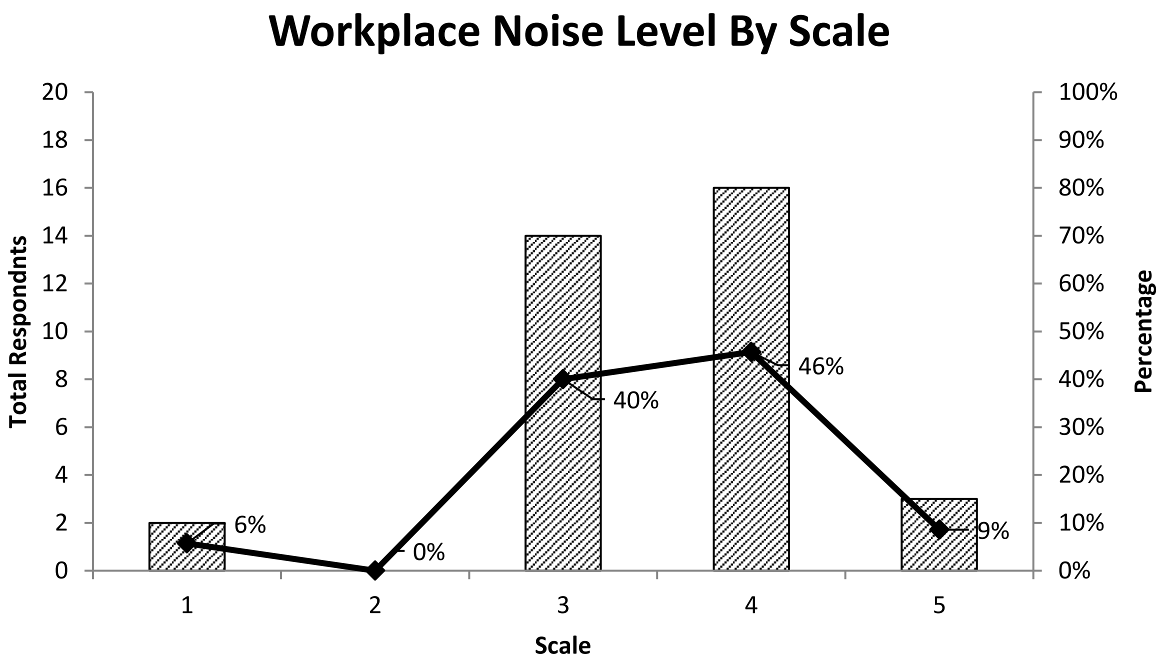

Fig. 1. Workplace noise level by scale

Social survey – Noise Effects Perception

Figure 2 below shows the noise effects percentage by scale. Annoyance, stress and job performance are the non-auditory effects of noise and hearing deterioration is the auditory effects of noise.

Based on Figure 2, annoyance, with 18 workers choosing Scale 1 and 2 (51.4%) has the highest impact on workers compared to stress (40.0%), hearing deterioration (14.3%) and job performance (2.9%).

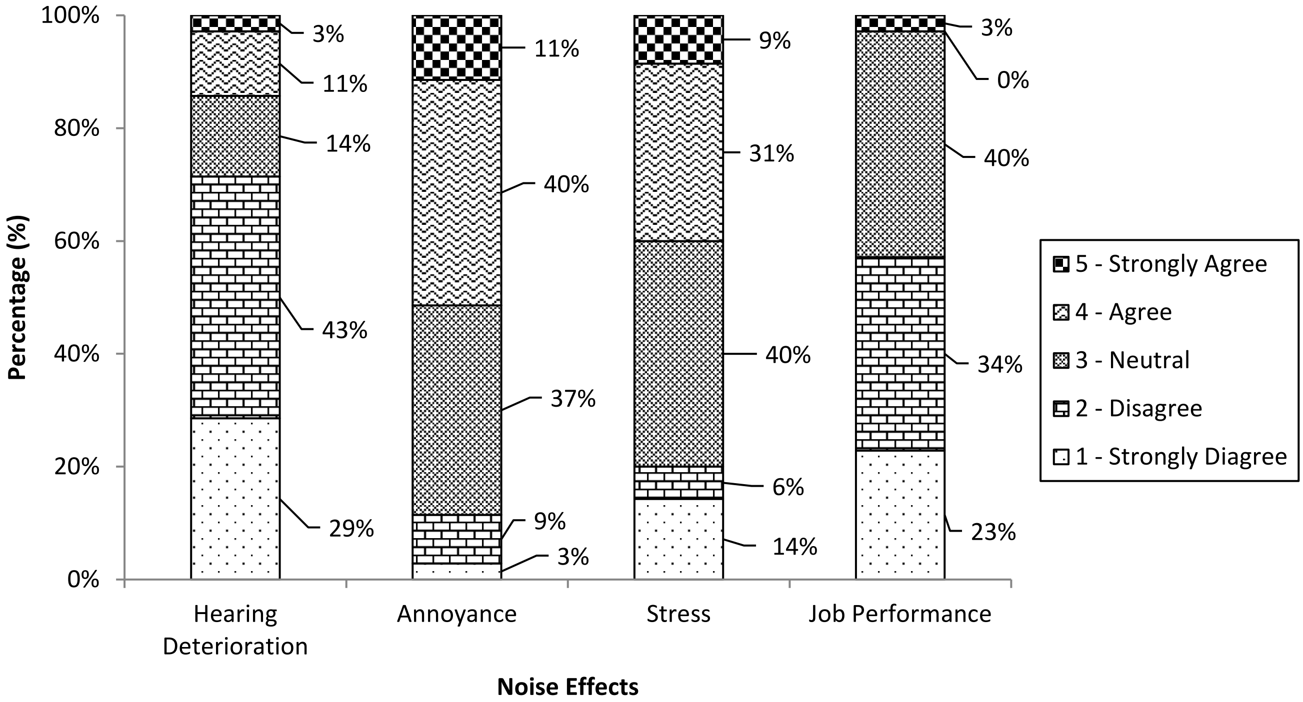

Fig. 2. Noise effects percentage by scale

Noise measurements

Sound level from all fourteen CNC machines at the machine shop area were measured. The result is shown in Figure 3 below. All machines L_{eq} are below action level of 85 dB(A).

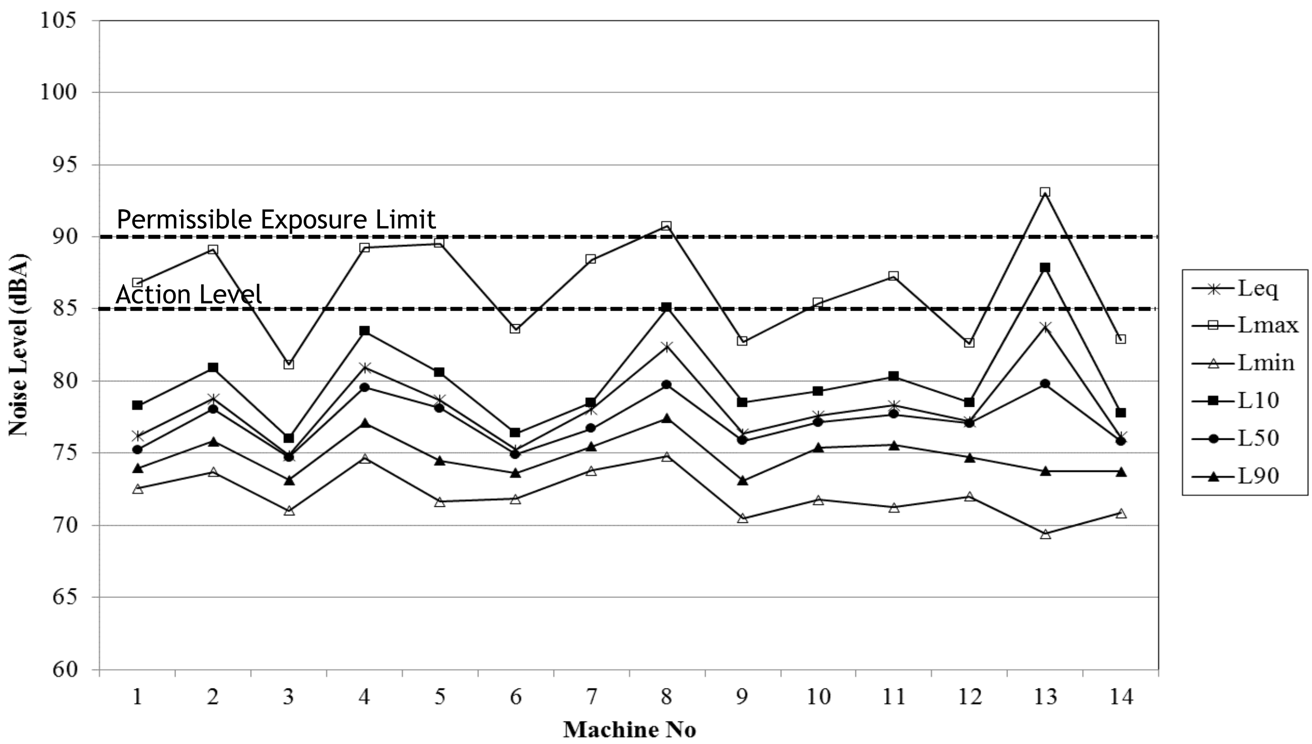

Fig. 3. Machine shop measurement results

However, based on L_{max}, there are a total of seven machines that achieved more than 85 dB(A), with two produced more than the permissible exposure limit of 90 dB(A).

In general, the value of L_{eq} for all fourteen machines at machine shop area are well below the limit set in the Factories and Machinery (Noise Exposure) Regulations, 1989.

The same pattern is observed at the remaining six work areas as the L_{eq} measured are also less than 85 dB(A) (Figure 4). In terms of L_{max}, the six work areas exceeded the action level of 85 dB(A), with three exceeding the permissible exposure limit of 90 dB(A). This result showed that the noise level in the manufacturing facility is not in control.

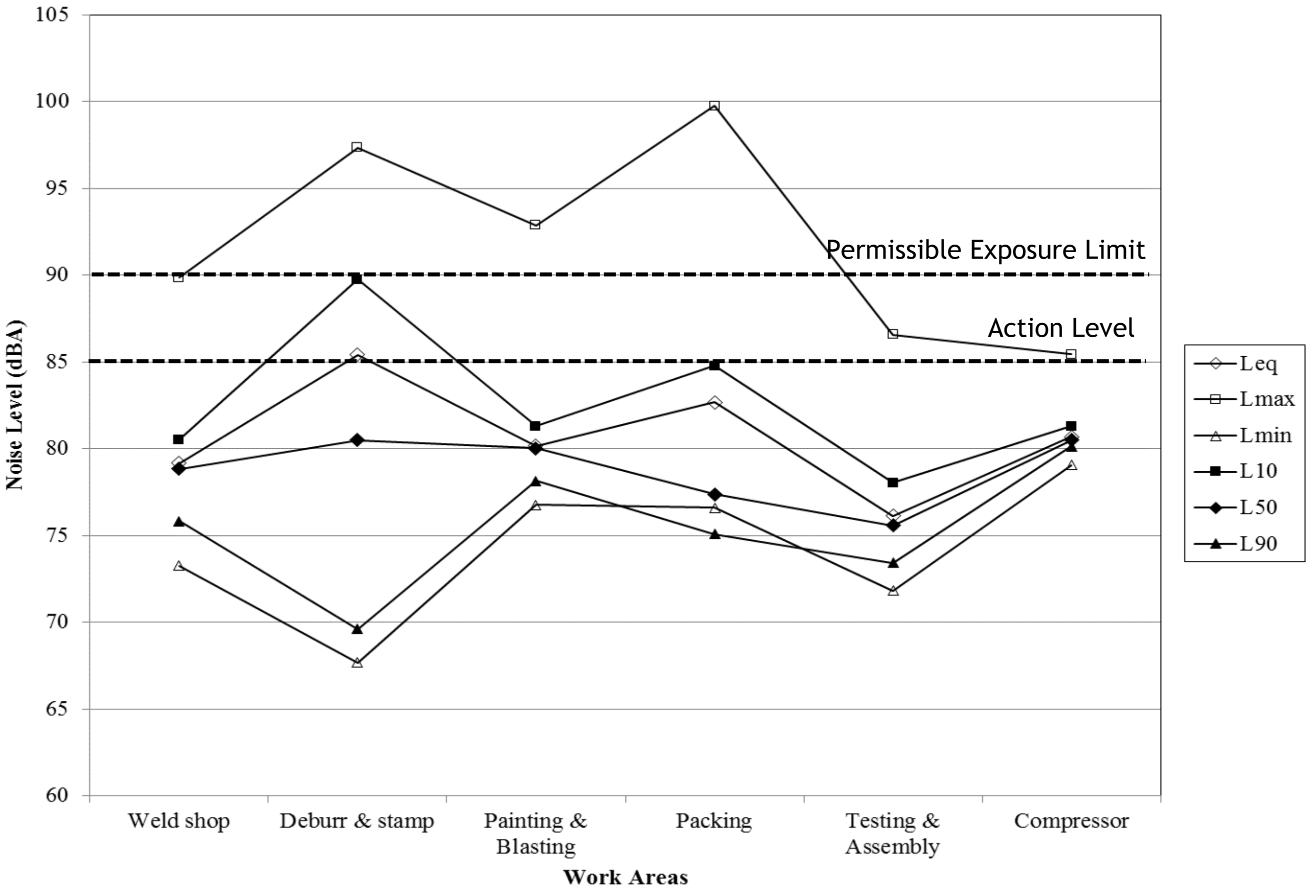

Fig. 4. Noise level by work areas

DISCUSSION

Logarithmic Calculation

To obtain a sound pressure value produced by various types of work areas for minimum and maximum sound level, logarithmic calculations was carried out using the formula:

$$\mathbf{SPL_{tot} = 10 \log_{10} \Sigma 10^{0.1SPL_i} (dB)}$$

All seven work areas shows exceptionally high SPL_{tot} which exceeded the action level, with four areas exceeding the permissible exposure limit as per Table 2 below. This data showed that the employees working in this manufacturing facility are exposed to loud noise with readings above the parameter mentioned in the Factories and Machinery (Noise Exposure) Regulation 1989.

Prevalence of Non-auditory effects of noise

As indicated in the results above, 46.0% of the respondents felt that their work areas has 'high' noise levels and 9.0% felt that the noise is 'extremely high', which means that more than half of the workers (55.0%) perceive that the noise levels is disturbing, while a total of 46.0% felt that the noise level is 'moderate' and 'low'.

In terms of the non-auditory effects of noise (Figure 2), annoyance and stress tops the list compared to hearing deterioration. To the best of the authors' knowledge, there is no previous studies that compare between the prevalence of auditory and non-auditory effects of noise. Most studies are focused on either the auditory, or the non-auditory effects of noise.

Table 2 - Total sound pressure level summary

Work Areas	SPL_{tot} (dB(A))	>Action Level 85 dB(A)?	>Permissible Exposure Limit 90 dB(A)?
Machine Shop	99.4	Yes	Yes
Weld Shop	89.9	Yes	No
Deburr & Stamp Area	97.3	Yes	Yes
Painting & Blasting Booth	92.9	Yes	Yes
Packing Area	99.7	Yes	Yes
Testing & Assembly	86.6	Yes	No
Compressor Area	85.4	Yes	No

Nevertheless, based on the results of this study, this shows that the prevalence of non-auditory effects of noise of the workers in this manufacturing plant is actually much higher than the auditory effects of noise.

The respondents that felt that the noise in the workplace had no profound effects on their hearing commented in the questionnaire form that they had been working for more than five years and had grown accustomed to the noise condition in their work areas. Their job performance is also not affected as they had been doing the routine tasks for years.

When comparing with the noise measurements results in Figure 3, 4 and Table 2, the data showed that the employees working in this manufacturing facility are exposed to auditory and non-auditory effects of noise due to the loud noise readings above the parameter mentioned in the Factories and Machinery (Noise Exposure) Regulation 1989.

Limitations of the study

There were several limitations to the design of this study. One of it is the information from the social survey. The accuracy of the data depends on the perception of the respondents and thus, there is a possibility that the respondents may not define the levels and effects of noise accurately.

The survey forms that was returned back to the authors was 35 even though there are a total of 105 workshop floor employees in the company. A higher response of employees would greatly increase the result of the research. Hence, the results of the study does not represent the whole company's noise level and effects of noise perception.

CONCLUSION

From the investigation results, it can be concluded that the noise level in this manufacturing facility are high and exceeded the national guideline. This support the result of the social survey carried out which exhibit the evidence that 55% of the workers felt that the noise levels in their workplace is high or extremely high. With regards to the auditory and non-auditory effects of noise, the non-auditory effects of noise are significant in this manufacturing facility. Thus, this type of effects should also be given as much attention as auditory effects of noise as it affect the mental and emotional well-being of the workers.

This study provide the management on the information of the manufacturing plant's noise level and to fulfil their responsibilities as stated in the Occupational Safety and Health Act, 1994 and conform to Factories and Machinery (Noise Exposure) Regulations 1989. The current existing noise control in the facility are by providing ear plugs, noise mapping monitoring and annual audiometric test. Other suitable countermeasures to protect the workers from noise exposure that can be carried out by (i) decreasing noise from sources, (ii) checking the Noise Reduction Rating (NRR) of the hearing devices, and (iii) usage of barriers.

ABBREVIATIONS

NIHL-Noise Induced Hearing Loss, WHO-World Health Organization, NRR-Noise Reduction Rating TIG – Tungsten Inert Gas, SLM – Sound Level Meter

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COMPETING INTERESTS

There is no conflict of interest.

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