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RESEARCH ARTICLE

Effects of Noise to the Industrial Workers at PCB Assembly Industry

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ABSTRACT - In today's environment, working conditions in factories, such as lighting, temperature, and noise, need to be studied to show the specific sections of a factory. Any sound that is annoying or exceeds 90 dBA may be considered noise. There are noise exposure issues at the production site of a PCB assembly industry in Johor Bahru. However, no research measures noise exposure in all selected departments at this company. Noise can cause negative emotions, delay sleep, disturb rest, and make it challenging to hear desirable sounds. However, studies have not been conducted on noise effects on industrial workers in the PCB Assembly Industry. This study investigated noise's effect on industrial workers. The SMT, Backend, and Warehouse departments were selected for the research study. Forty questions on different aspects of noise effects were prepared and served to 150 workers in three departments. Responses from workers were collected, which served as data for further analysis. A well-known statistical test called the Chi-Square test was used to determine the significance of noise effects. At the level of significance α = 0.10 and α = 0.05, it was found that the Physiological Effect, Hearing Loss Effect, Auditory Effect, Psychological Effect and sleep disturbance were significant. A discussion is highlighted, and the paper concludes with the study's essential findings.

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1.0 INTRODUCTION

Industrial working environments must comply with lighting, temperature, and noise regulations to prevent injuries and poor product quality. High noise levels in the PCB Assembly Industry in Johor Bahru contribute to ergonomic hazards, affecting safety and performance. Noise is subjective and can be measured scientifically, with loudness affecting tasks and health issues like hypertension and insanity.

Previously stated that high noise level at workplace causes the workers to work unsafely. May our PCB Assembly Industry at Johor Bahru have noise exposure issues, mainly at the production site? After investigating found that there is no research measuring the level noise exposure at departments has been done at this company. On other hand, no study has been conducted on the effects of noise on industrial workers at this firm. This paper presents the outcome of the investigation to find noise exposure level at working departments and the impact of the noise level towards the industrial workers at PCB Assembly Industry. The methodology adopted for this study is described, and the results are presented. A discussion is highlighted, and the paper concludes with the study's essential findings.

The aim of the project to investigate the noise level at different working departments and the impact of the noise level towards the industrial workers in the PCB Assembly Industry. There are mainly three objectives to achieve of this project thesis. Firstly, to investigate the noise condition at three different departments within a company. Secondly, to survey the effect of noise among industrial workers at three different departments within a company. Thirdly, to analyze the effect of noise among industrial workers at three different departments within a company.

This paper consists of five chapters, including an introduction, a literature review, a specific of the thesis experiment, research methodology, and findings. The introduction explains the thesis's inspiration and aims, while the literature review outlines relevant information. Chapter 3 describes the research methodology, research sites, questionnaire design, and statistical method. Chapter 4 presents findings on noise levels at four different company sites and respondents' answers. The conclusion concludes with a general discussion and conclusions. An appendix provides details and a bibliography of reading resources used throughout the investigation.

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2.0 LITERATURE REVIEW

2.1 Ergonomics

Ergonomics is the process of designing tasks that suit the worker, making work safer and more efficient. It incorporates human capabilities and constraints to create a safe, pleasurable, and productive environment. Ergonomics is crucial as the musculoskeletal system is affected by uncomfortable positions, extreme temperatures, and repetitive movements. Ergonomics improves employee comfort and productivity by matching work demands to the talents of the workforce. It is beneficial for both employees and companies, as it provides a safe work environment, boosts competence, and improves job efficiency. Ergonomics can significantly reduce occupational injuries by providing workplace evaluations and ergonomic training. OSHA reports that over 30 million people are exposed to dangerous workplace noise levels, causing 125,000 employees to experience severe and permanent hearing loss.

2.2 Sound and Noise Terminology

Noise and melody are both types of sounds, with music being the most pleasing to our ears. Noise is defined as any unnecessary disturbing sound that interferes with our hearing ability. The difference between sound and noise depends on who is listening and what is happening around them. Sound is made when something vibrates and people hear it through air or other mediums. A pure tone is defined by its frequency and amplitude, with pitch and loudness being their subjective opposites. Noise is often described as a sound or noise of sufficient volume to irritate or interfere with conversation. The human ear can detect various sound pressure levels (SPLs) from 0.00002 N/m2 to 20 N/m2. The decibel scale, a logarithmic scale used to measure sound intensity, is used to represent the observed sound pressure ratio to a reference level. The hearing mechanism in the ear detects sound waves and converts them into information for communication with the brain. Powerful sounds may cause hearing loss, and working with a wide range of normal sound pressures is difficult. The decibel scale is more convenient as it reduces the numerical scale to a more reasonable range.

2.3 Noise-Induced Pathology of the Ear

The decibel scale represents a sound, and the ear converts atmospheric sound waves into nerve impulses that are processed by the auditory nerve in the brain. The ear is divided into three anatomical divisions: outer, middle, and inner. The outer ear contains the pinna, external auditory canal, and ear drum, while the middle ear is an air-filled bone chamber connected to the environment. The ossicular system transmits eardrum vibrations to the inner ear, which discriminates between sounds of different frequencies. The auditory ossicles determine ear sensitivity to different frequencies. Hearing loss can occur due to age-related effects, such as persistent threshold shifts in audiometry. As sensitivity to specific frequencies fades due to ageing or injury, the strength with which a stimulus can be recognized increases, leading to temporary threshold alterations.

2.4 Ear Protection for Industrial Workers

Earplugs can protect the ear from excessive noise by creating an airtight barrier between the external auditory canal and the surroundings. They can achieve SPL reductions of up to 40 dB at the eardrum. However, simple ear protection is inadequate when noise exceeds 140 dB, as vibrations can infiltrate the auditory system. Earplugs are compact, portable, and less expensive than earmuffs. (Christensen et al., 2019) They can be worn with long hair or protective headgear. However, some workers take longer to wear earplugs and may not be ideal for regular usage due to cleanliness concerns. Earmuffs should provide more robust and consistent protection, and most head sizes can be supported with a single-size adjustable muff. Ear protection manufacturers in the US must provide statistics on noise attenuation, but less protection may be provided due to testing conditions. Acceptance of ear protection is often a major problem in the industry, as workers exposed to extreme noise often refuse to wear it due to discomfort, interference with oral communication, and degraded task feedback. However, ear shields may reduce sound levels and improve speech recognition.

2.5 Measurement of Sound and Noise Exposure

Sound level meters give a variety of good intensity measurements. The sound pressure level (SPL) is measured using the dB (linear) scale. If the effect on the listener is the primary concern, the frequency of the sound must be considered. The dB(A) scale is the most often used. A weighting network selectively boosts specific frequencies when sound is measured using the dB(A) scale. This procedure is like tweaking the tone control on a current high-end amplifier. The pressure levels of the different frequencies are added to determine the sound level (LS). Numerous technologies produce loud sounds at a particular frequency centered on the 60 Hz mains frequency or their harmonics. The weighted sound level is at least 20 dB lower despite the high appropriate pressure levels. It's because sounds with frequencies below 500 Hz make the ear insensitive. These specialized scales are designed to assess noise with robust and pure tone components. An example is noise from jet engines.

2.6 Effect of Noise on Task Performance

Noise can impair acoustic performance by concealing crucial sounds and making tasks more difficult. Non-auditory elements also impact the number of performance declines during a task. (Le Prell, 2019) For instance, the difficulty of the task in a quiet environment and the motivation of the person doing the activity. (Battista & Montgomery, 2021) illustrates that some conditions of increased arousal, noise may boost task performance. The primary neural system condition that promotes preparation for action is arousal. The reticular activating system (RAS) in the brain stem controls everything. Sleep is associated with a reduction in RAS activity. Noise can impair performance by interfering with the mental processes required to complete a job. Stressful noise, vibration, or heat levels might increase job performance by boosting arousal under specific situations. The best working environment for a task may only sometimes be stress-free. (Bien et al., 2020) Generally, the noise is deafening and two activities are being performed concurrently and predictable noise. (Burns et al., 2019). However, physiological effects, psychological effects, auditory effects, hearing loss effects, and sleep disturbances can all contribute to the well-being and performance of industrial workers.

Physiological impacts such as tiredness, musculoskeletal disorders (MSDs), respiratory problems and heat stress can significantly impact workers' physical health and performance. (Tao et al., 2020) As a result, lower productivity, increased absenteeism and a higher risk of accidents and injuries. Long working hours and high-pressure conditions. The demanding nature of industrial jobs can lead to psychological impacts including stress, anxiety and burnout. These psychological elements may harm employees' well-being, happiness and mental health. According to (Cotana et al., 2023), machinery, equipment and procedures causes high noise levels in industrial environments. Long-term exposure to loud noise may damage the ears and cause communication issues, tinnitus and temporary or permanent hearing loss. (Hahad et al., 2019) These auditory side effects may make it harder for workers to complete activities, raise the possibility of accidents and lower their quality of life. (Jafari et al., 2019) For industrial workers, hearing loss can have serious repercussions. Their capacity to properly communicate, comprehend directions, and recognise danger signs may be impacted. Social exclusion, fewer career possibilities, and a lower quality of life contribute to hearing loss.Workplaces with high-stress levels, irregular work schedules, and shift work can interrupt employees' sleep. (Kim et al., 2019) Lack of sleep and low-quality sleep can affect cognitive performance, reduce awareness, and raise the chance of mishaps and mistakes.

3.0 PROPOSED METHOD

Our research was conducted in four phases to achieve our objectives. The sound was categorized as noise when the sound level exceeded 90 dBA for our study. The Surface Mounted Technology (SMT) Department, Backend Department and Warehouse Department was chosen that have machinery.

3.1 Noise-Induced Pathology of the Ear

Surface Mount Technology (SMT) is an innovative method of component assembly where the components are mounted on top of a bare PCB that acts as a mounting point. Therefore, accomplishing the accurate and effective positioning of the SMT components on the PCB pad requires several procedures that require sophisticated and expensive equipment. The SMT department chooses three points at each station such as Point 1, Point 2 and Point 3 to measure the noise level for seven days.

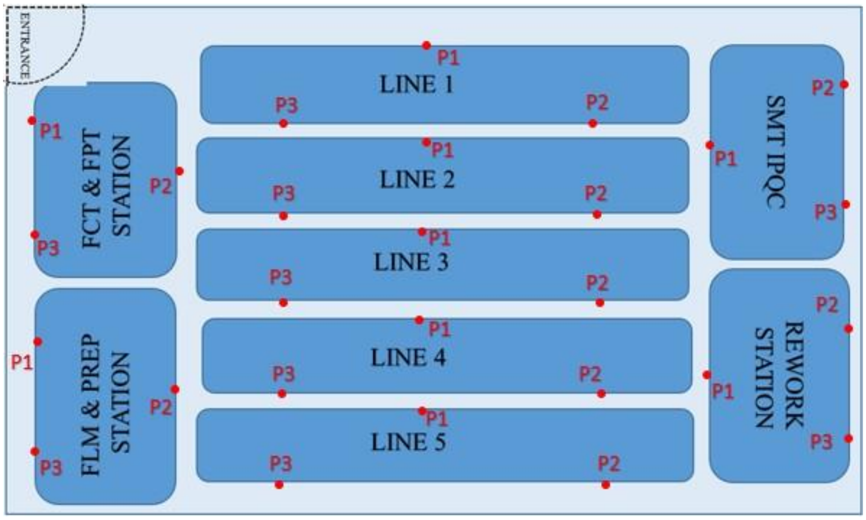

Figure 1 Plant Layout of SMT Department with Stations

3.2 Backend Department

The backend-of-the-line (BEOL) is the second primary stage of the PCBA manufacturing process. Any component having leads or wires that must be installed on a board by plugging them through holes will operate well with thru-hole technology. On the opposite side of the board, you must solder the additional lead component. Moreover, all the tests such as the Functional test, 5DX test, and ICT test carried out determine the process's success or failure. Point 1, Point 2 and Point 3 are chosen at the Backend Department to measure the noise level for seven days.

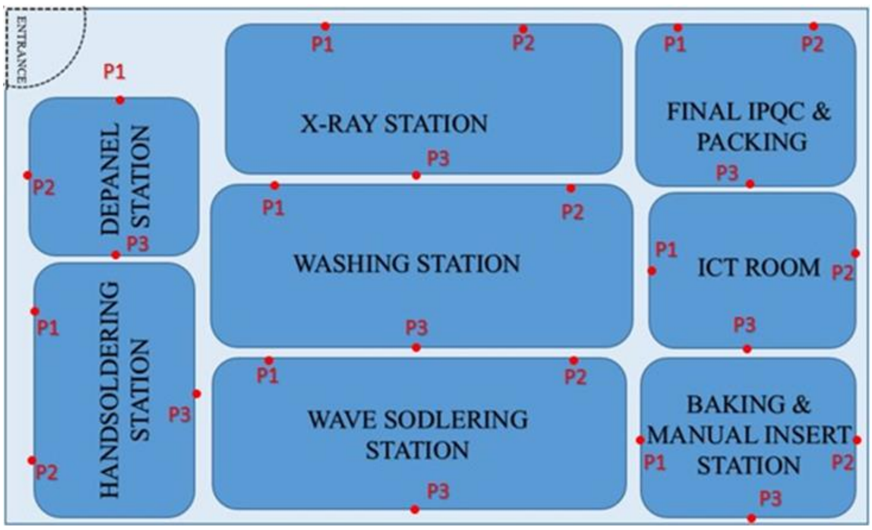

Figure 2 Plant Layout of Backend Department with Stations

3.3 Warehouse Department

In warehousing, tangible products or inventory are kept in a warehouse or storage space before being sold or dispersed. It is simple to trace an item's location, date it arrived, how long it has been there, and the amount on hand due to warehouses' orderly storage and protection of goods. Point 1, Point 2 and Point 3 are chosen at the Warehouse department to measure the noise level for seven days.

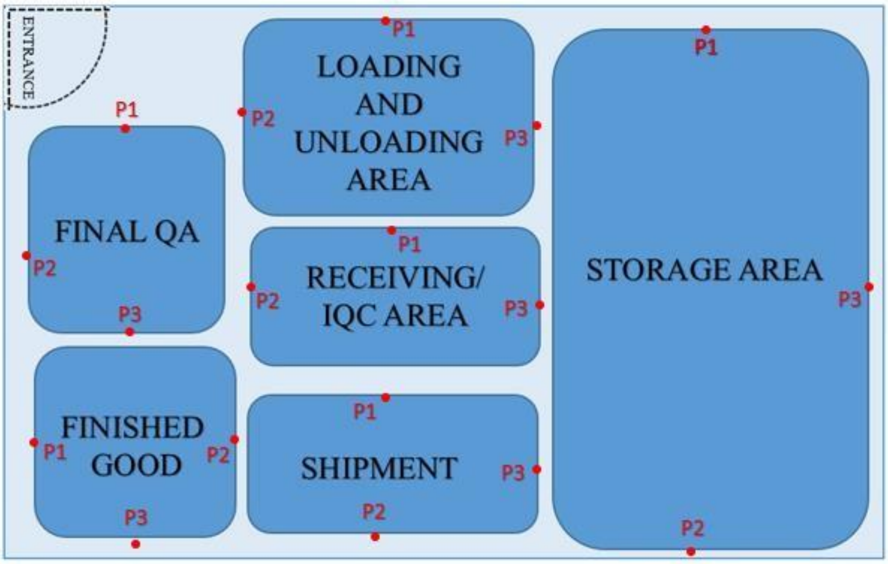

Figure 3 Plant Layout of Warehouse Department with Stations

3.4 Phase 1 : Measure Noise Exposure using Noise Dosimeter

The actual noise to which employees were subjected was documented for each site. These were completed by standing at the worker's positions for 5 minutes and recording the maximum and average noise levels at those points. This research was conducted during morning shift workers. For this purpose, the Logging Noise Dose Meter Type 4443 was used.

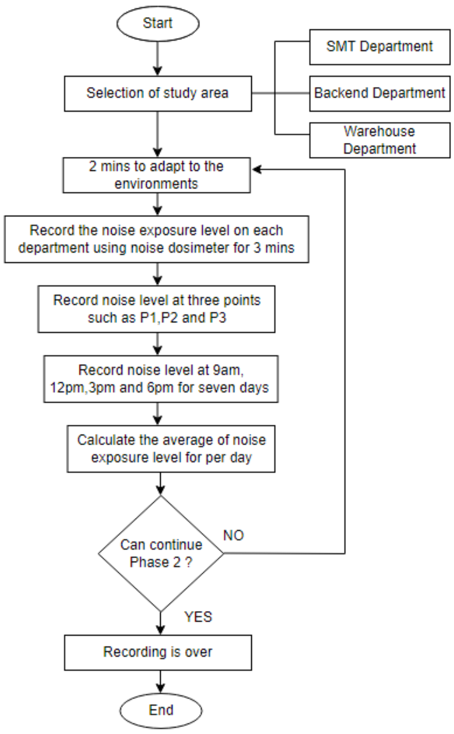

Figure 4 Flowchart Noise Level of Measurement.

3.5 Phase 2: Present and Analyse Recorded Data using Histogram

The data processing and analysis were conducted to identify the highest noise exposure on the production floor measured by the dosimeter. The average noise level exposure was computed by recording the actual noise to which personnel were exposed at three locations within each department. Then, the registered noise level status will be processed and analyzed using histograms.

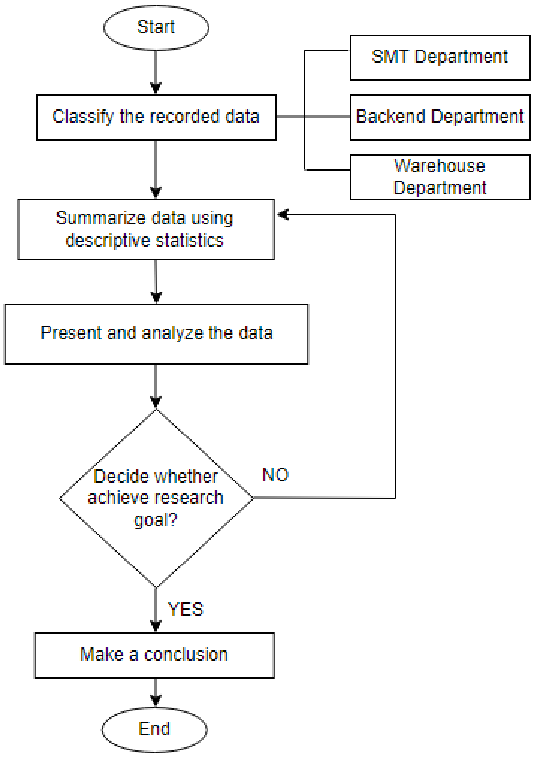

Figure 5 Flowchart Noise Level of Measurement.

3.6 Phase 3: Design and Collect Data from Questionnaire Survey

The questionnaires used in this research were created according to the guidelines in Appendix A and two different sorts of responses were used to gather the results. The responses for the categories were YES and NO. The 40 questions on the questionnaires covered the following types of aspects:

a) Physiological effects (items nos.: 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16)
b) Hearing loss effects (items nos.: 17,18,19,20)
c) Auditory effects (items nos.: 21,22)
d) Psychological effects (items nos.: 23,24,25,26,27,28,29,30,31,32,33,34)
e) Sleep disturbances effects (items nos.: 35,36,37)
f) Protection of hearing variables (items nos.: 38,39,40)

The questionnaires were distributed to the study respondents at each research site. If the workers cannot understand the questionnaires, then we are clearly explained.

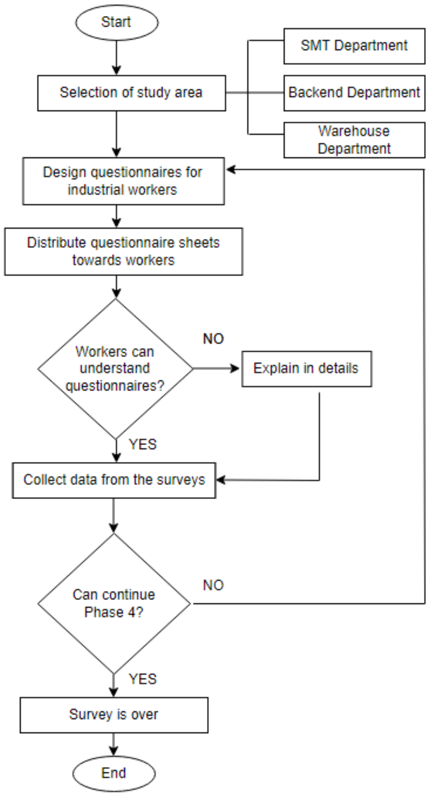

Figure 6 Flowchart of Questionnaire Survey

3.7 Phase 2: Present and Analyse Recorded Data using Histogram

The data processing and analysis were carried out to identify the response of workers based research survey on the effect of noise apparent on the production floor. The observation tool used is the Workers Respondents of Noise Exposure Questionnaire. In the data processing and analysis, the results of the questionnaire are going to be tabulated to determine the highest presence of the effect of noise on a specific department. Then, the tabulated questionnaire results will be processed and analyzed using Chi-Square test method.

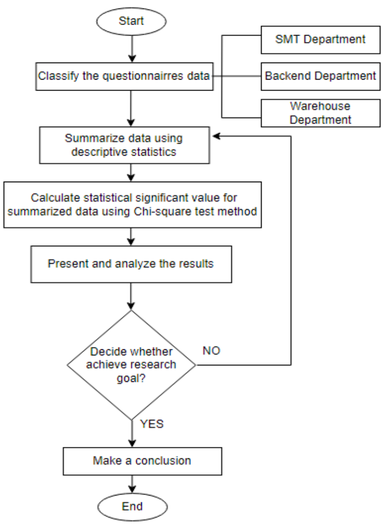

Figure 7 Flowchart of Analyse Data on Questionnaire Survey.

4.0 RESULTS AND DISCUSSION

Data were gathered, and statistically analyzed, and conclusions were drawn in by the approach outlined in the methodology. Significant decisions were made in light of the findings. One hundred fifty completed the questionnaires, distributed equally across the study departments (50 respondents × three departments).

4.1 Status of Noise Level Study

Work currently being carried out on industrial noise includes studying the noise levels at different points in the SMT Department, the Backend Department, and the Warehouse Department, as well as investigating how noise affects the industrial employees at these three departments. The data was gathered directly from each department. The seven-day noise status data were collected from Table 1 and Figure 8 display the current noise level graphically.

Table 1 Status of Equivalent Noise at SMT, Backend and Warehouse Department for Seven Days

Station	Day 1 (dBA)	Day 2 (dBA)	Day 3 (dBA)	Day 4 (dBA)	Day 5 (dBA)	Day 6 (dBA)	Day 7 (dBA)	Average for Seven Days (dBA)
SMT Department								
Line 1	85.95	85.90	85.90	85.95	85.93	85.95	86.00	85.94
Line 2	86.05	86.05	86.05	86.05	86.05	86.05	86.05	86.05
Line 3	86.00	86.15	85.98	85.98	85.98	86.00	85.98	86.01
Line 4	86.10	86.10	86.10	86.15	86.15	86.15	86.20	86.14
Line 5	86.10	86.08	86.08	86.10	86.08	86.05	86.08	86.08
FLM & Kitting	86.15	86.13	86.10	86.10	86.15	86.15	86.15	86.14
FCT & FPT	86.00	86.10	86.00	86.00	86.00	86.00	86.00	86.00
SMT IPQC	86.00	86.05	86.00	86.05	86.05	86.00	86.00	86.05
Rework	85.80	85.90	85.80	85.80	85.85	88.00	85.80	86.14
Backend Department								
Depanel	89.00	89.00	89.03	89.00	89.05	89.05	89.00	89.03
Hand-Soldering	89.20	89.18	89.18	89.20	89.20	89.18	89.15	89.18
X-ray	89.00	88.98	88.98	88.00	89.00	89.00	88.95	88.98
Washing	97.50	97.50	97.50	97.50	97.50	97.50	97.50	97.50
Wave Soldering	98.25	98.25	98.25	98.25	98.25	98.25	98.25	98.25
Baking & Manual Insert	88.95	88.90	88.93	88.95	88.95	88.95	88.90	88.93
ICT Room	89.45	89.45	89.45	89.45	89.45	89.45	89.45	89.45
Packaging & Final IPQC	89.15	89.15	89.15	89.15	89.15	89.15	89.15	89.15
Warehouse Department								
Final QA	82.20	82.20	82.20	82.20	82.20	82.20	82.20	82.20
Finished good	72.40	72.40	72.40	72.40	72.40	72.40	72.40	72.40
Loading & Unloading Area	89.40	89.40	89.40	89.40	89.40	89.40	89.40	89.40
Receiving/IPQC Area	86.15	86.10	86.15	86.20	86.10	86.15	86.10	86.15
Shipment	86.15	86.15	86.15	86.15	86.15	86.15	86.15	86.15
Storage area	78.05	78.10	78.30	78.20	78.10	78.20	78.15	78.05

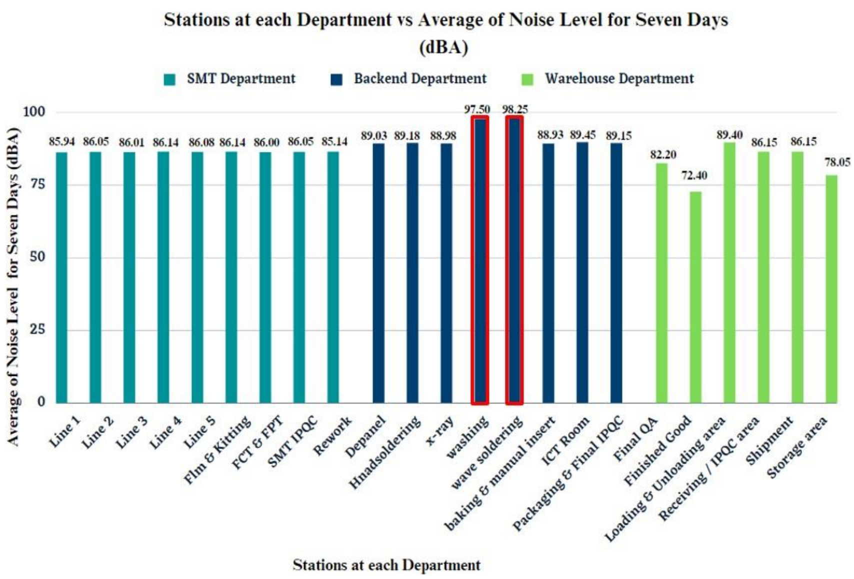

Figure 8 Graphical Comparison of Noise Level for Seven Days at Three Departments

The average noise level for the SMT Department, Backend Department, and Warehouse Department over a seven-day period is depicted in Figure 8 above. The SMT Department's average noise level ranges from 85.20 dBA to 87.05 dBA. The Backend Department's average noise level ranges from 88.95 dBA to 98.25 dBA. The Backend Department's average noise level ranges from 75.40 dBA to 88.40 dBA. According to OSHA's permissible exposure limit (PEL) is 90 dBA for all workers for an 8 hours per day. Therefore, the highest noise for seven days at three departments was 94.25 dBA at Washing Station and 96.50 dBA at Wave Soldering Station which is highlighted in red colour. The lowest noise level during those seven days is 72.40 dBA at Finished Good Station. Otherwise, the other departments seem noisy but remain below 90 dBA.

4.2 Investigation on the Impacts of Noise on Industrial Workers in the SMT Department, Backend Department and Warehouse Department

The effects of noise on industrial employees were investigated by distributing questionnaires. The responses to each question on the questionnaires were obtained directly from the employees. The statistical value, χ^2 for each corresponding five effects are calculated using Chi-square test and the results were presented below.

Table 2 The Statistical Test Results for Five Relevant Effects.

No.	Type of Effect	Relationship between the type of effect at different proposed departments	
		$\alpha = 0.10$	$\alpha = 0.05$
1	Physiological Effect	Significant	Significant
2	Hearing Loss Effect	Significant	Significant
3	Auditory Effect	Significant	Significant
4	Psychological Effect	Significant	Significant
5	Sleep Disturbance	Significant	Significant

This survey research was carried out mainly on engineering science and socio- science. Physiological Effects, Hearing Loss, and Auditory Effects are categorised as Engineering Science. Typical statistical significance for Engineering Science studies would be $\alpha = 0.10$ or less for survey research. However, Psychological effects and Sleep disturbance are classified as Social Science. Typical statistical significance for social science studies would be $\alpha = 0.05$ or less for survey research. Chi-square test values for five types of effects were calculated based on $\alpha = 0.10$ and $\alpha = 0.05$ for this research study. According to the summarised result obtained in Table 2, all the types of effects are more than the pre-specified alpha of $\alpha = 0.10$ and $\alpha = 0.05$. So, all the impacts on Engineering Science and Social Science are statistically significant for this research study. Thus, it is abundantly apparent that the noise level at work affects industrial workers.

5.0 CONCLUSION

This paper reports some important conclusions drawn based on the present work. Based on the investigation on noise levels towards industrial workers, three objectives were successfully achieved. The first goal on investigation of noise level in three departments within a company established using Phase 1 and Phase 2 and the results are distributed by histogram. The second goal of the survey on effect of noise among industrial workers at three different departments within a company conducted using Phase 3 and the data analyzed corresponding to the five effects. The third goal on analyzing the effect of noise among industrial workers at three different departments within a company performed using Phase 4 and proven significantly using Chi-Square Test Method.

6.0 RECOMMENDATIONS

Based on the above result, all effects bring the noise level down to a safe level. Then, management should provide hearing protection equipment to every worker and monitoring that everyone uses it while doing activities in noisy areas. Meanwhile, company authorities need to take several actions to mitigate these effects. Firstly, provide proper training on awareness of noise exposure. Secondly, implementing noise control measures like choosing low-noise tools and machinery. Thirdly, perform maintenance on machinery and equipment every six months. Lastly, give penalties to workers for those never wear hearing protection when work at noisy environment.

7.0 ACKNOWLEDGEMENT

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8.0 REFERENCES

[1] Battista, E. B., & Montgomery, Z. A. (2021). Henry Ford Health System Scholarly Commons Manufacturing Workers Have a Higher Incidence of Carpal Tunnel Syndrome.

[2] Bien, E., Davis, K., & Gillespie, G. (2020). Home healthcare workers' occupational exposures.*Home Healthcare Now*, *38*(5), 247–253. https://doi.org/10.10097/NHH.0000000000000891

[3] Burns, K. N., Sayler, S. K., & Neitzel, R. L. (2019). Stress, health , noise exposures , and injuries among electronic waste recycling workers in Ghana. 9, 1–11.

[4] Prall, J., & Ross, M. (2021). The Impact of Physical Therapy Delivered Ergonomics in the Workplace: A Narrative Review. *Indian Journal of Physiotherapy and Occupational Therapy - An International Journal*, *15*(3), 27–36. https://doi.org/10.37506/ijpot.v15i3.16160

[5] Prell, C. G. Le. (2019). Effects of noise exposure on auditory brainstem response and speech-in- noise tasks : a review of the literature tasks : a review of the literature. *International Journal of Audiology*, *58*(S1), S3–S32. https://doi.org/10.10080/14992027.2018.1534010

[6] Christensen, J. A., Sis, J., Kulkarni, A. M., & Chatterjee, M. (2019). Effects of Age and Hearing Loss on the Recognition of Emotions in Speech. *Ear and Hearing*, *40*(5), 1069–1083. https://doi.org/10.10097/AUD.0000000000000694

[7] Cotana, F., Asdrubali, F., Arcangeli, G., Luzzi, S., Ricci, G., Busa, L., Goretti, M., Tortorella, A. A. V., Pulella, P., Domenighini, P., Gambacorta, V., Guattari, C., Cirimbilli, F., Nicolini, A., Nataletti, P., Annesi, D., Sanjust, F., & Cerini, L. (2023). Extra-Auditory Effects from Noise Exposure in Schools: Results of Nine Italian Case Studies. *Acoustics*, *5*(1), 216–241. https://doi.org/10.3390/acoustics5010013

[8] Hahad, O., Kröller-Schön, S., Daiber, A., & Münzel, T. (2019). Auswirkungen von Lärm auf das Herz-Kreislauf-System. *Deutsches Arzteblatt International*, *116*(14).

[9] Jafari, M. J., Khosrowabadi, R., Khodakarim, S., & Mohammadian, F. (2019). The effect of noise exposure on cognitive performance and brain activity patterns. *Open Access Macedonian Journal of Medical Sciences*, *7*(17), 2924–2931. https://doi.org/10.3889/oamjms.2019.742

[10] Kim, S., Kim, Y., Lim, S. S., Ryoo, J. H., & Yoon, J. H. (2019). Long Commute Time and Sleep Problems with Gender Difference in Work–Life Balance: A Cross-sectional Study of More than 25,000 Workers. *Safety and Health at Work*, *10*(4), 470–475. https://doi.org/10.10016/j.shaw.2019.08.001

[11] Liu, Q., Wang, X., Liu, J., An, C., Liu, Y., Fan, X., & Hu, Y. (2021). Physiological and psychological effects of nature experiences in different forests on young people. *Forests*, *12*(10). https://doi.org/10.3390/f12101391

[12] Shabani, F., Alimohammadi, I., Abolghasemi, J., Dehdari, T., & Ghasemi, R. (2020). The study of effect of educational intervention on noise annoyance among workers in a textile industry. *Applied Acoustics*, *170*, 107515. https://doi.org/10.10016/j.apacoust.2020.1007515

[13] Tao, Y., Chai, Y., Kou, L., & Kwan, M. P. (2020). Understanding noise exposure, noise annoyance, and psychological stress: Incorporating individual mobility and the temporality of the exposure-effect relationship. *Applied Geography*, *125*(June), 102283. https://doi.org/10.10016/j.apgeog.2020.10022.