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Implementation and Effectiveness of Engineering Noise Control: Evaluation in Malaysia's Manufacturing Sector

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Abstract

Occupational noise-induced hearing disorders, also known as ONRHD remain the most prevalent occupational disease in Malaysia, driven by excessive exposure in the manufacturing sector. This study evaluated the sound pressure level (SPL) as well as implementation and effectiveness of engineering noise controls in three high-risk subsectors: electrical/electronic, metal/steel, and food. A total of 796 machines were assessed using sound level meters (SLM) (Class 1). More than half of the machines (53.5%) exceeded the safe threshold of 82 dBA, while 35.6% operated above the Noise Exposure Limit (NEL) of 85 dBA. Subsector analysis revealed the food industry as the highest risk, with 43.4% of machines exceeding 85 dBA, several surpassing 100 dBA and approaching 110 dBA. The metal/steel subsector recorded 38.3% above NEL, while electrical/electronic subsector had 28.6%, albeit with significant variability across machine groups such as grinders, stamping presses, and air compressors. Of the 184 machines with engineering controls, insulation was the most common (54.3%), yielding an average reduction of –8.2 dBA. Control combinations, such as insulation with distance, achieved greater attenuation (–10.9 dBA), though inconsistent performance was observed, often due to poor selection, design, or maintenance. Notably, 75 machines continued to exceed 85 dBA despite controls, highlighting implementation gaps. There was no significant difference in SPL between machines with and without controls ($p>0.05$). Overall, only 13.7% of machines required no further intervention. These findings underscore the urgent need for tailored engineering controls guided by octave band analysis, stronger enforcement of noise regulations, and machine-specific mitigation strategies to reduce NIHL risk in Malaysia's manufacturing sector.

1. Introduction

In In Malaysia, the manufacturing sector is a key contributor to economic growth but is inherently associated with high noise levels due to extensive use of heavy machinery. The regulatory framework, including the Occupational Safety and Health (Noise Exposure) Regulations 2019 and the Industry Code of Practice, mandates risk assessment, engineering controls, administrative measures, and provision of hearing protection devices (HPDs) for workers exposed above action levels [1]. However, compliance remains inconsistent, particularly in industries with aging machinery and financial constraints [2]. Occupational noise-induced hearing disorder (ONRHD) has remained the most reported occupational disease since 2013. In 2023, the Department of Occupational Safety and Health (DOSH) recorded 11,747 occupational disease and poisoning cases, of which 8,155 were confirmed occupational diseases and 6,754 cases (≈83%) were ONRHD [3].

Noise exposure is a well-established hazard in manufacturing, contributing significantly to noise-induced hearing loss (NIHL). In Malaysia, approximately 26% of workers in general manufacturing are affected [4], [5]. Higher prevalence has been reported in palm oil mills, ranging from 54.2% to 75.5% [6], [7], while exposure-based assessments further demonstrate that severity of hearing loss increases with noise intensity [8]. These values exceed the global estimate of 21.3% among industrial workers [9], highlighting Malaysia's comparatively higher burden. Noise exposure varies depending on machinery, processes, and workplace layout. In chemical industries, compressors, pumps, and turbines generate noise levels between 85–115 dBA [10], while metal fabrication and woodworking processes often exceed 90 dBA [11], [12]. Additional sources such as hydraulic machines, lathes, and automotive equipment including forklifts and pneumatic tools further contribute to hazardous noise levels [13], [14]. Understanding these sources is essential for implementing effective control strategies.

In this study, noise levels were evaluated against the excessive noise threshold of 82 dB(A) and the Noise Exposure Limit (NEL) of 85 dB(A) as defined by regulations [15]. Results showed that more than half of the machines exceeded 82 dBA, with 35.6% surpassing 85 dBA, particularly in the food and metal/steel subsectors. These findings are consistent with trends observed across Asia, where rapid industrialisation has increased NIHL risks [16]. Comparison with previous studies indicates that noise levels in the metal sector remain substantial, although slightly lower than earlier reports of 87–94 dBA and peaks up to 95.2 dBA in grinding processes [17], [18]. Across manufacturing sectors, common noise sources include high-speed machinery, compressors, and processing systems, often exceeding safe limits.

Although the hierarchy of controls prioritizes engineering solutions, industries in Malaysia continue to rely heavily on HPDs due to lower cost [2]. Engineering controls such as acoustic enclosures, damping materials, and vibration isolation have demonstrated measurable noise reductions [19]. In practice, mitigation strategies in Malaysia include maintenance scheduling and soundproofing in PCB assembly and plastic manufacturing industries [20], [21]. More advanced approaches integrating enclosures, anti-vibration systems, and monitoring technologies have also proven effective [22]. Furthermore, customised engineering controls and proper spatial reconfiguration are essential for achieving optimal noise reduction [23]. Despite these efforts, the persistence of ONRHD indicates gaps in implementation and effectiveness of existing control measures. Therefore, this study evaluates machinery noise levels and current engineering controls to develop targeted and practical guidelines for improving noise management, particularly in the metal manufacturing subsector. The study was planned according to two primary reference documents: the Industry Code of Practice for the Management of Occupational Noise Exposure and Hearing Conservation 2019 and the Guidance on Occupational Noise Control 2024 [1].

1.1 Research Design

In this study, a mixed methods approach was used with the quantitative study involved measuring noise levels for each activity or process at the designated workplaces using a sound level meter, along with statistical analysis of the collected data. The qualitative study focused on reviewing noise-related information and conducting direct expert observations regarding existing engineering control measures, their weaknesses, and gaps, as well as best practices for noise engineering controls.

1.2 Sampling Strategy

A limitation of this study is the use of purposive sampling, as the 25 manufacturing sites were selected based on pre-existing DOSH records of occupational noise-induced hearing loss. While this approach was intentional to evaluate known high-risk environments, it introduces a selection bias. Consequently, the high prevalence of excessive noise reported here may overstate the average noise levels across the broader Malaysian manufacturing sector and cannot be perfectly generalized to industries or facilities with lower historical risk profiles.

1.3 Research Instrument

The measurement equipment to be used in this study is a Class 1 Sound Level Meter and calibrator (Table 1). The noise measurement equipment complied with the standards set by the International Electrotechnical Commission (IEC). The sound level meters meet the requirements of IEC 61672, and the sound calibrator complies with the specifications outlined in IEC 60942. The noise measurement equipment has a valid calibration period not exceeding 12 months from the previous calibration date by an accredited laboratory.

Table 1 *List of measuring instruments*

No.	Measuring instrument	Serial no.	Model	Calibration expiry date
1.	Casella sound level meter class 1	2425384	CEL-63X	3 December 2025
2.	Rion sound level meter class 1	00410142	NL-52	11 April 2026
3.	Casella sound calibrator class 1	2525869	CEL-120/1	26 November 2025
4.	Larson davis precision acoustic calibrator class 1	3513	CAL200	11 April 2026

1.4 Sampling Procedure

Before entering site, the researcher contacted the selected companies to access relevant information such as noise risk assessment reports, lists of noise generating machines or equipment and layout plans. During the data collection, area monitoring activities were carried out. Sound level meter was used to identify machines that generate sound exceeding the excessive noise, 82dB(A) and noise exposure limit (NEL), 85dB(A) [15]. The machines were checked for any existing engineering controls implementation. This was safe and practically achievable for 155 out of 184 machines equipped with engineering controls (84.2%). For the remaining 29 units, the controls could not be dismantled due to machine design constraints or safety risks, leaving baseline difference data unavailable for those specific configurations. This evaluates the effectiveness of existing engineering control measures as well as weaknesses or gaps in the current control system. The sound level meter was calibrated using a sound calibrator before and after field measurements, in accordance with the calibration procedure of 114.0 dB at 1000 Hz, and the deviation between pre- and post-calibration must not exceed 0.5 dB. Measurements are conducted at four positions around the noisy machinery or equipment (front, back, left, and right) in accordance with the recommendations outlined in the Guidance on Occupational Noise Control 2024 which adopts internationally recognized acoustic measurement standards for determining emission sound pressure levels at workstations and other specified positions [23]. Each sampling point is recorded for a duration of 10 seconds using a fast time-weighting setting at 1-meter distance and 1.55-meter height.

1.5 Data Analysis

The data was analysed using SPSS Version 26. Descriptive statistics, Chi-square measure of association and independent sample t-test were used to test data.

2. Results

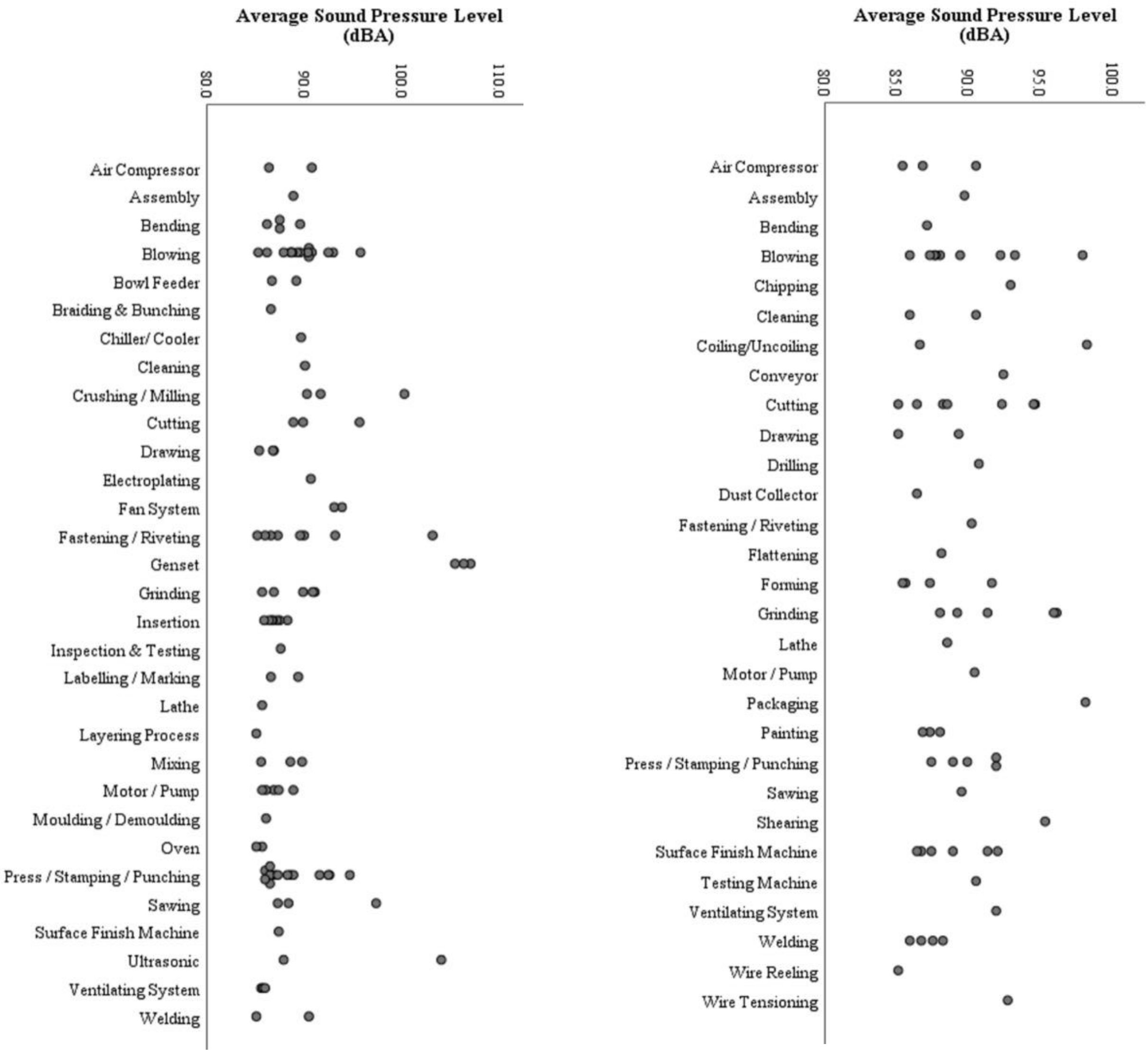
Across all three subsectors, a total of 796 machines were assessed for noise emission. Table 2 shows the distribution of the machines across the three subsectors and different permissible limits as defined in the Occupational Noise Exposure Regulation, 2019. Overall, 53.5% (17.9% + 35.6%) of machines exceeded the safe noise exposure threshold of 82dBA, with 35.6% producing noise above 85dBA, the level requiring urgent control interventions. A chi-square test indicated that the difference in noise emission level across subsectors was statistically significant ($\chi^2 = 46.07$, $p < 0.001$) confirming variation in machinery noise emission by subsector. The Food Subsector showed the highest prevalence with 43.4% of machines above 85 dBA, followed by the Metal/Steel Subsector (38.3%), and the Electrical/Electronic Subsector (28.6%). These findings highlight that the Food subsector is at higher risk for noise exposure, followed by Metal/Steel and Electrical/Electronic subsectors.

Table 2 *Distribution of machines in subsectors by noise exposure limits*

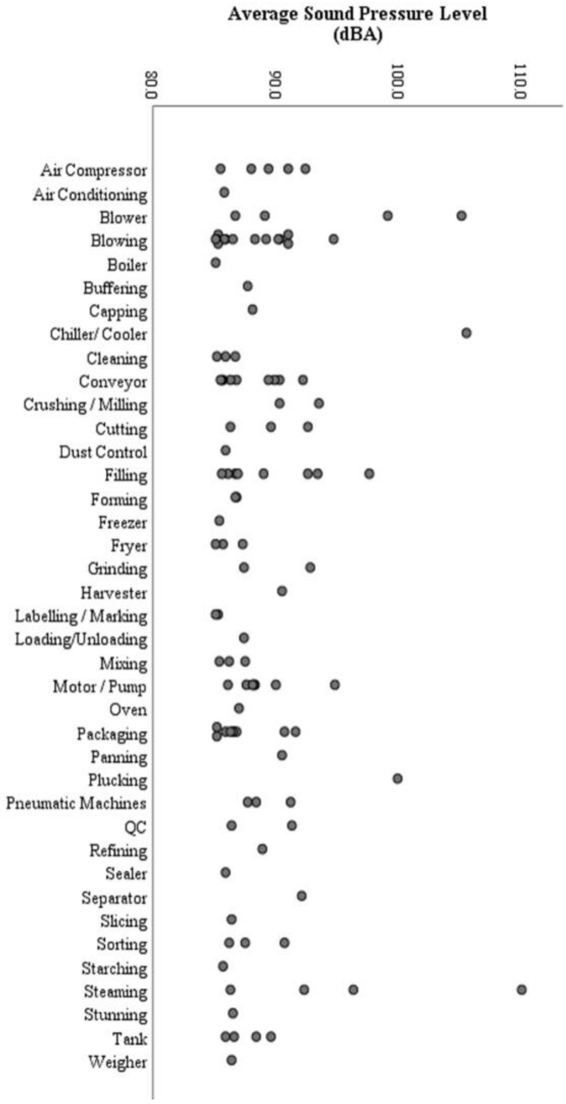
Subsector	Total Site	Total Machines	Distribution of Machines by Noise Exposure Limits, n (%)			χ2 (df)	p value
			≤82dBA	> 82dBA – 85dBA	> 85dBA		
Electrical/ Electronic	10	360	208 (57.8)	49 (13.6)	103 (28.6)	46.07 (4)	< 0.001*
Metal/ Steel	8	180	83 (46.1)	28 (15.6)	69 (38.3)		
Food	7	256	79 (30.9)	66 (25.8)	111 (43.4)		
Total	25	796	370 (46.5)	143 (17.9)	283 (35.6)		

*Significant at p<0.05

The scatter plot in Fig. 1a, 1b, 1c shows the average SPL values for machine groups across Electrical/Electronic, Metal/Steel, and Food Subsectors that exceed NEL 85dBA. The machines were grouped based on site observations and machine specifications, grouping equipment with similar noise-generating processes. Several machine groups, particularly in the Food and Metal/Steel subsectors, show SPLs above 100 dBA, with some reaching close to 110 dBA, indicating extremely hazardous exposure levels. In contrast, the Electrical/Electronic Subsector generally records slightly lower SPLs, with a higher concentration of machines between 82–90 dBA, though several machine groups still exceed 95 dBA. The spread of data points across all subsectors demonstrates considerable variability within each machine group, suggesting that noise exposure is not only subsector-specific but also highly dependent on the type of machinery used.



(a) **(b)**



(c)

Fig. 1 *Scatterplot of SPL >85dBA, for machine groups in subsectors: (a) Electrical/Electronic; (b) Metal/Steel; (c) Food*

Analysis on the existing noise engineering control revealed that 184 machines were equipped with engineering control. The prevalence of the type of engineering control, the SPL level and SPL reduction achieved, is given in Table 3 whereas the effectiveness of the control in producing noise below NEL is given in Table 4. As shown in Table 3, Insulation was the most widely applied engineering control (54.3%, 100/184 machines), achieving an average sound pressure level (SPL) of 81.3 ± 6.8 dBA with a reduction of –8.2 dBA. This suggests that Insulation is relatively effective in attenuating noise. Other controls such as vibration isolation (12.5%), distance (4.9%), and combinations with dampers, silencers, and absorption materials were much less common. Distance and Silencer also demonstrated moderate effectiveness, –6.6 dBA and –5.9 dBA respectively, though they were less frequently implemented in comparison to insulation. Combinations of controls tend to provide additional noise reduction, for Insulation with Distance achieved an average reduction of –10.9 dBA, while Insulation with Absorption and with Vibration Isolation both reduced noise by–6.9 dBA.

However, some multi-control combinations were less successful in reducing the noise below 85dBA, such as combining five control methods (Insulation, Distance, Silencer, Vibration Isolation, Damper) unexpectedly resulted in the highest SPL (106.3 ± 1.1 dBA) though being the highest reported reduction too (–11.3 dBA). This suggests that the baseline noise level may already be extremely high and that multiple controls are not sufficient to bring the levels below the permissible level. Similarly, combinations such as Absorption, Insulation & Vibration Isolation still showed high SPLs (>90 dBA), indicating limited effectiveness, possibly due to wrong choice of control, poor implementation, machinery design, and poor maintenance of the control method itself.

Table 3 *Implementation of engineering controls (n=184)*

	n (%)	SPL Avg	SPL Range	SPL Difference
Damper	4 (2.2)	84.9 ± 3.0	80.7 - 87.4	na
Distance	9 (4.9)	83.7 ± 7.9	70.0 - 90.5	-6.6
Insulation	100 (54.3)	81.3 ± 6.8	67.7 - 97.6	-8.2
Vibration Isolation	8 (4.3)	82.5 ± 3.9	74.4 - 86.6	na
Absorption & Insulation	7 (3.8)	82.4 ± 3.2	79.0 - 88.0	-6.9
Insulation & Damper	4 (2.2)	81.6 ± 13.6	66.1 - 95.7	na
Insulation & Distance	7 (3.8)	85.0 ± 8.9	69.8 - 100.3	-10.9
Insulation & Silencer	6 (3.3)	78.2 ± 6.7	70.6 - 86.8	na
Insulation & Vibration Isolation	23 (12.5)	84.1 ± 4.7	74.0 - 94.7	-6.9
Silencer & Distance	1 (0.5)	86.9*	-	na
Absorption, Insulation & Damper	1 (0.5)	90.5*	-	na
Absorption, Insulation & Vibration Isolation	1 (0.5)	92.6*	-	na
Insulation, Distance, Silencer, Vibration Isolation, Damper	2 (1.1)	106.3 ± 1.1	105.5 - 107.1	-11.3
Silencer	7 (3.8)	84.4 ± 2.5	81.0 - 88.0	-5.9
Absorption, Insulation & Silencer	2 (1.1)	85.8 ± 1.4	84.8 - 86.8	na
Vibration Isolation & Damper	1 (0.5)	82.3*	-	na
Insulation, Distance, Vibration Isolation	1 (0.5)	83.5*	-	na

*Only ONE (1) machine unit, hence True value reported.
na = SPL difference data is not available

As tabulated in Table 4, 83 machines in electrical / electronic subsector, 62 machines in food subsector and 39 in metal / steel subsector. Among these, 109 machines (60.2%) had noise levels below the exposure limit of 85dBA. This accounts for 50 units (45.9%) in the electrical / electronics, 25 (64.1%) units in metal / steel and 34 (54.8%) in the food subsector respectively. The remaining 75 machines still exceeded 85dBA despite having engineering controls, indicate the needs of additional and appropriate control measure to tackle the noise emission issue.

In the Electrical/Electronic Subsector, machines without controls demonstrated a significantly higher proportion of machines operating at or below the Noise Exposure Limit (NEL) compared to those with controls (74.7% vs.60.2%, χ^2=6.56, p=0.010). However, the difference in average SPL between controlled (81.9 ± 8.46 dBA) and uncontrolled machines (80.5 ± 6.72 dBA) was not statistically significant (t=1.47, p=0.142). In the Metal/Steel as well as Food Subsector, no significant differences were observed between machines with and without controls, both in terms of prevalence above the NEL (p=0.724 & 0.742) and average SPL (81.7 ± 6.05 vs. 83.6 ± 6.21 dBA, p=0.090 & 84.1 ± 4.81 vs. 84.1 ± 6.06 dBA, p=0.962).

When considering all subsectors collectively, machines with controls showed higher proportion exceeding the NEL (40.8%) compared to uncontrolled machines (34.0%), and no statistically significant difference was detected for either prevalence (p=0.096) or average SPL (82.6 ± 6.97 vs. 82.4 ± 6.61 dBA, p=0.734). These findings suggest that while some benefit of engineering controls is observed in the Electrical/Electronic subsector, their overall implementation across subsectors has not consistently reduced noise exposure to levels below the NEL.

Overall, 13.7% (109/796) of the machines assessed requires no further action, as the current existing control able to maintain the noise below the NEL 85dBA. Additional control measures or modifications to the existing control are required for 9.4% of machines assessed (75/796), that have existing but ineffective engineering controls. The remaining three-quarters of the machines assessed (76.9%) had no engineering controls and specifically 35.6% of machines (283 /796) that produced noise beyond NEL need quick action to control noise emissions below 85dBA.

Table 4 *Effectiveness of engineering control implementation*

Subsector	n (%)	Prevalence, n (%)		Statistics[a]		Average SPL,	Statistics[b]	
		SPL ≤ NEL	SPL > NEL	χ2	p-value	mean ± SD	t	p-value
Electrical/ Electronic								
Machines with control	83 (23.1)	50 (60.2)	33 (39.8)	6.56	0.010*	81.9 ± 8.46	1.47	0.142
Machines without control	277 (76.9)	207 (74.7)	70 (25.3)			80.5 ± 6.72		
Metal/ Steel								
Machines with control	39 (21.7)	25 (64.1)	14 (35.9)	0.13	0.724	81.7 ± 6.05	-1.707	0.090
Machines without control	141 (78.3)	86 (61.0)	55 (39.0)			83.6 ± 6.21		
Food								
Machines with control	62 (24.2)	34 (54.8)	28 (45.2)	0.11	0.742	84.1 ± 4.81	-0.048	0.962
Machines without control	194 (75.8)	111 (57.2)	83 (42.8)			84.1 ± 6.06		
Overall								
Machines with control	184 (26.0)	109 (59.2)	75 (40.8)	2.83	0.096	82.6 ± 6.97	0.34	0.734
Machines without control	612 (74.0)	404 (66.0)	208 (34.0)			82.4 ± 6.61		

*Significant at p<0.05; [a] Chi-square Measure of Association, [b] Independent Sample t-test

The manufacturing sector globally, and particularly in Malaysia, frequently presents occupational noise levels exceeding safe thresholds, necessitating robust interventions to prevent noise-induced hearing loss among workers. In Malaysia, despite legislative advancements like the Occupational Safety and Health Act 1994, compliance and enforcement remain inconsistent, especially within high-risk manufacturing environments. This global trend is exacerbated in developing Asian economies, where the rapid industrialization, exemplified by Malaysia, often outpaces the implementation of comprehensive health and safety regulations [16].

In this study, it was found that more than half of the machines assessed exceeded the excessive noise level of 82 dBA and 35.6% produced noise levels above 85 dBA. The highest prevalence found in the Food subsector, emitting extremely hazardous levels above 100 dBA, reaching close to 110 dBA. While global literature on specific engineering controls in the food industry remains limited, these findings indicate an alarming situation in Malaysia's localized food processing setups that demands urgent mitigation strategies. Following this is the Metal/Steel subsector, with an average SPL level around 81 dBA, slightly lower than the past research. Mamat and Naim, who conducted research in the metal fabrication industry, reported that noise levels in the factory ranged from 87 to 94 dBA, especially in fabrication zones, with high-pitched machinery like compressors and grinders being the main contributors [17]. Similarly, Rosli, Karim, and Razak recorded noise levels as high as 95.2 dBA during the grinding process of palm oil machinery components [18]. Most Electrical/Electronic machines were between 82–90 dBA though some still exceeded 95 dBA. A significant risk in the electronics manufacturing sector is linked to high-speed assembly lines, soldering, and conveyor belt operations that generate continuous background noise.

Like the current study, literature suggests that across various manufacturing sectors in Malaysia, common sources of occupational noise include heavy machinery, high-speed tools, air compressors, and processing systems. These sources often generate noise exceeding the 85 dBA threshold set by occupational safety standards, posing a substantial risk to workers' auditory health. Effective noise control strategies are necessary to mitigate these risks and enhance workplace safety. Though, noise exposure control often results in reliance on personal protective equipment and administrative controls rather than more effective, long-term engineering control which is the most practicable and first line of defence in minimizing noise as it aims to reduce noise at its source or along its transmission path.

The findings of this study indicate that the application of engineering controls across the three subsectors has deeply inclined towards Insulation that works by blocking sound transmission through mass and damping layers, often using dense and multi-layered materials. By incorporating sound-insulating materials like dense barriers, acoustic panels, and specialized windows and doors, it is possible to minimize the intrusion of external noise and prevent the escape of internal noise [13]. Though, this technique is especially effective in controlling low-frequency noise. A wide implementation of Insulation as the primary control may not guarantee successful noise attenuation, due to dominant frequency factors, which is also true for other controls. As proof, the industries with implementation of noise engineering controls did not consistently achieve the intended goal of reducing machine noise to levels below the NEL.

In the metal subsector then again, engineering controls such as acoustic enclosures, vibration isolation, and noise-dampening materials have shown measurable reductions in noise levels [7], [19]. For example, retrofitting pressing machines with damping materials and acoustic barriers has reduced ambient noise by up to 10–15 dB(A) in certain facilities. In many cases, it is the best practice to control noise via integrated approach. For instance, noise mitigation in PCB assembly and plastic manufacturing in Malaysia has been approached through scheduled maintenance to minimize mechanical faults, and soundproofing of injection molding machines, respectively [20]. A study by Chis, Cioca, Badea, and Cristea addresses noise exposure in rubber manufacturing environments by integration of noise-isolating materials, machine enclosures, and anti-vibration mounts, coupled with digital monitoring systems, to effectively control ambient noise levels [21]. In this study too, combinations such as insulation with distance provided greater reduction (–10.9 dBA). This is somewhat aligned with that reported by Zainal Abidin and Anthony Nait who reasoned that a custom-made engineering control is preferred, and spatial reconfiguration is crucial before modifications to machine layout [22].

3. Conclusion

In summary, one-third of the machines assessed emitted noise above the NEL, thus requiring urgent intervention, particularly in Food Subsector. As for control, Insulation remains the most used control, either as stand-alone or used in combination with other methods such as distance or silencing. However, results also highlight variability in effectiveness, depending on the machine type, baseline noise levels, and implementation quality. This brought to an insight that, while engineering controls can effectively attenuate noise emission, careful choice of the right control, that is suitable for machine design and process is of paramount important. One most successful way of achieving this is through understanding of the dominant noise frequency through octave band analysis. Furthermore, the sustained prevalence of noise-induced hearing impairment among Malaysian industrial workers underscores the critical need for a paradigm shift towards proactive noise control at the source, moving beyond reactive, individual-centric protective measures.

Finally, it is important to acknowledge the limitations regarding the generalizability of these findings. This study employed purposive sampling, intentionally selecting 25 manufacturing facilities with established histories of excessive noise exposure and reported occupational noise-induced hearing loss (NIHL) cases to DOSH. While this targeted approach was necessary to evaluate the practical effectiveness of existing controls in known high-risk environments, it introduces a selection bias. Therefore, the high prevalence of non-compliance and elevated sound pressure levels reported in this study may overstate the average noise profile of the broader Malaysian manufacturing sector and cannot be broadly generalized to industries or facilities with inherently lower risk profiles. Future studies should incorporate a randomized, cross-sectional sampling strategy across a wider variety of industrial subsectors to establish a more comprehensive baseline for nationwide engineering control compliance.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors are responsible for the study conception, research design, data collection, data analysis, result interpretation and manuscript drafting.

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