Lecture Notes in Mechanical Engineering

Mohd Hasnun Arif Hassan
Mohd Nadzeri Omar
Nasrul Hadi Johari
Yongmin Zhong *Editors*

Proceedings of the 2nd Human Engineering Symposium

HUMENS 2023, Pekan, Pahang, Malaysia

Springer

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ISSN 2195-4356 ISSN 2195-4364 (electronic)
Lecture Notes in Mechanical Engineering
ISBN 978-981-99-6889-3 ISBN 978-981-99-6890-9 (eBook)
https://doi.org/10.1007/978-981-99-6890-9

Preface

Technological advancements have significantly benefited humans. Technology has led to the development of ergonomic tools and equipment that improve human comfort, reduce strain, and enhance overall productivity. From adjustable office chairs to ergonomic keyboards, these innovations promote proper posture and reduce the risk of musculoskeletal disorders. When it comes to road safety, technology has played a pivotal role in saving lives and preventing accidents. Advanced driver assistance systems (ADAS) equipped with sensors, cameras, and artificial intelligence algorithms help detect potential hazards, warn drivers, and even intervene if necessary. In the realm of sports technology, advancements have revolutionized training methodologies and performance analysis. Athletes now have access to wearable devices that monitor their biometric data, providing insights into their physical condition, performance metrics, and injury prevention. Further, technological advancements have led to sophisticated tools and methods for studying the human body's mechanics and movement. High-speed cameras, force sensors, and motion-tracking systems enable researchers to gain deeper insights into human locomotion, joint mechanics, and muscle activation patterns. These findings help design better prosthetics, rehabilitation programs, and ergonomic solutions tailored to individual needs.

The "Unlocking Human Potential: The Future of Human Engineering" symposium seeks to delve into the cutting-edge field of human engineering, exploring the possibilities of augmenting and optimizing human capabilities through advancements in science, technology, and design. This symposium brings together experts from various disciplines to discuss and showcase innovative approaches, methodologies, and ethical considerations in the realm of human engineering. From neuroenhancement to prosthetics, cognitive augmentation to genetic engineering, this symposium aims to stimulate insightful discussions and inspire the creation of a future where human potential knows no bounds.

Pekan, Malaysia — Mohd Hasnun Arif Hassan

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About the Editors

Dr. Mohd Hasnun Arif Hassan earned his first degree in Mechanical Engineering from the Technische Hochschule Bingen, Germany, in 2010. During the final year of his undergraduate study, he was offered a scholarship by Universiti Malaysia Pahang (UMP) to pursue a Master's degree in Mechanical Engineering at the University of Malaya in Kuala Lumpur, which he graduated with distinction in 2012. After that, he embarked on his Ph.D. journey at UMP where he studied about the head injury sustained by soccer players due to heading manoeuvre. He completed his Ph.D. study in 2016 and then continued to serve UMP as a senior lecturer. His research interests include finite element modelling of the interaction between human and sports equipment, instrumentation of sports equipment, and injury prevention particularly with regards to sports and traffic accidents. His work aims to apply engineering principles in sports not only to enhance the performance of an athlete but also to prevent injuries.

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Dr. Nasrul Hadi Johari obtained his Ph.D. in Biofluid Mechanics from Imperial College London, United Kingdom. He is currently a senior lecturer at the Faculty of Mechanical and Automotive Engineering Technology, Universiti Malaysia Pahang. Dr. Johari's research activities include computational modeling of blood flow, tissue mechanics, and mass transport in the cardiovascular system, with applications ranging from evaluating the hemodynamic performance of medical devices to predict the outcome of endovascular interventional procedures. He is also interested in computational and experimental modeling of the interaction between human

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Development of Noise Risk Assessment (NRA) and Management System

Kirubalini Asok Kumar, Nur Syafiqah Fauzan, Mirta Widia, Ezrin Hani Sukadarin, Nor Liyana Man, and Mohd Ikhwan Mohd Ibrahim

Abstract Noise has become an occupational hazard for workers. Many studies proved that occupational noise-related issues still exist even though thorough inspection, observation, implemented control measures, and medical examinations were carried out. This study focused on the development of a Noise Risk Assessment and Management System based on Industry Code of Practice (ICOP) for Management of Occupational Noise Exposure and Hearing Conservation 2019, Occupational Safety and Health (Noise Exposure) Regulation 2019 and Guidelines on Management of Occupational Noise-Related Hearing Disorder 2021. The system was developed by using Microsoft Access. Two industry experts reviewed and validated the ready system to ensure the content was relevant and complied with the relevant legal requirements and their applicability in industries. The selected experts were among the competent noise risk assessor and safety and health manager. The System Usability Scale (SUS) test and System Functionality and Capability Scale Assessment form were used to validate and verify the system. The SUS score indicates 75.5, which is graded as B. It shows that the system can be used in industry with some improvements that should be made. At the end of this research, a successful

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M. H. A. Hassan et al. (eds.), *Proceedings of the 2nd Human Engineering Symposium*, Lecture Notes in Mechanical Engineering,
https://doi.org/10.1007/978-981-99-6890-9_32

Noise Risk Assessment and Management System has been developed to be used in industries.

Keywords Noise risk assessment · Noise · Safety system · Management system

1 Introduction

In most industries, human or employee exposure to noise is growing daily. Noise has become an occupational hazard for workers. According to the Centers for Disease Control and Prevention (CDC), 22 million workers are exposed to possibly harmful noise at work every year [1]. Overexposure to noise at or over 85 dB(A) for extended periods of time can result in irreversible hearing loss, tinnitus, and trouble understanding speech in noisy environments. Long-term exposure to sounds louder than 90 dB(A) can cause severe damage to the auditory system, leading to neurasthenia, headaches, hypertension, and other ailments [2].

According to the Department of Occupational Safety and Health (DOSH) [3], employers must provide hearing protection devices and adequate training on the usage of the device. Frequent monitoring must be done according to the law until the risk is reduced among workers. During noise monitoring, the company will conduct a noise risk assessment, which is recommended to be recorded digitally. The majority of firms and sectors use manual records of assessments. According to ICOP [4], within one month of the assessment at the targeted premises, the noise risk assessor should give the occupier of the premises the data and report from the noise risk assessment. The company's owner must keep the hardcopy report delivered by the appointed assessor for a minimum of 30 years.

Allowing a database system would be organised, user-friendly, and simple to manage. A manager or accessor can quickly locate any employee record when all information is in a database. Makhilan et al. [5] proved that converting a manual method to a new development of assessment systems for food premises is useable and succeeded.

Therefore, this study will focus on developing a noise risk assessment and management system. This system was developed to track employees' data who have been assessed with noise risk and manage noise risk among employees. All of the data collected will be utilised to develop a mitigation or corrective action plan to be implemented at the workplace to decrease or eliminate the noise risk.

2 Methodology

2.1 Framework Development

The prototype system was developed based on the designed framework (Fig. 1). Industry Code of Practice (ICOP) for Management of Occupational Noise Exposure and Hearing Conservation 2019, Occupational Safety and Health Act (OSHA) as Noise Exposure Regulations 2019 and Guidelines on Management of Occupational Noise-Related Hearing Disorders 2021. This system was designed for the targeted end-user, who is an employer, assessor, safety and health practitioner and employee in industries.

2.2 System Development by Microsoft Software

Microsoft Access and Microsoft Word were used to develop this system. Microsoft Word was used to build this system's framework, and Microsoft Access was used to develop the prototype system. The development of a system in Microsoft Access will make it easier for users to enter data, make data entries and other connected elements. The framework was developed based on noise risk assessment forms, acts, regulations and industry codes of practice.

This system comprises many components that allow the assessor and occupational safety and health practitioner (OSHP) to search for employees who have been documented in the system related to occupational disease, personal noise monitoring, online noise-related training attended by employees and many more. This system will be created to transition from manual to digital record keeping.

2.3 System Usability Scale (SUS) Test

The System Usability Scale (SUS) test [6] was done among targeted end users to assess the effectiveness of this system prototype. SUS is a standardised questionnaire designed to assist end-user in determining a system's Usability. The system usability scale is a ten-item attitude measure used in systems engineering. A global view of subjective usability ratings is provided via a Likert scale. This test was evaluated using the user's total SUS score. A grade was assigned based on the overall score using the Curved Grading Scale as per Table 1 [7].

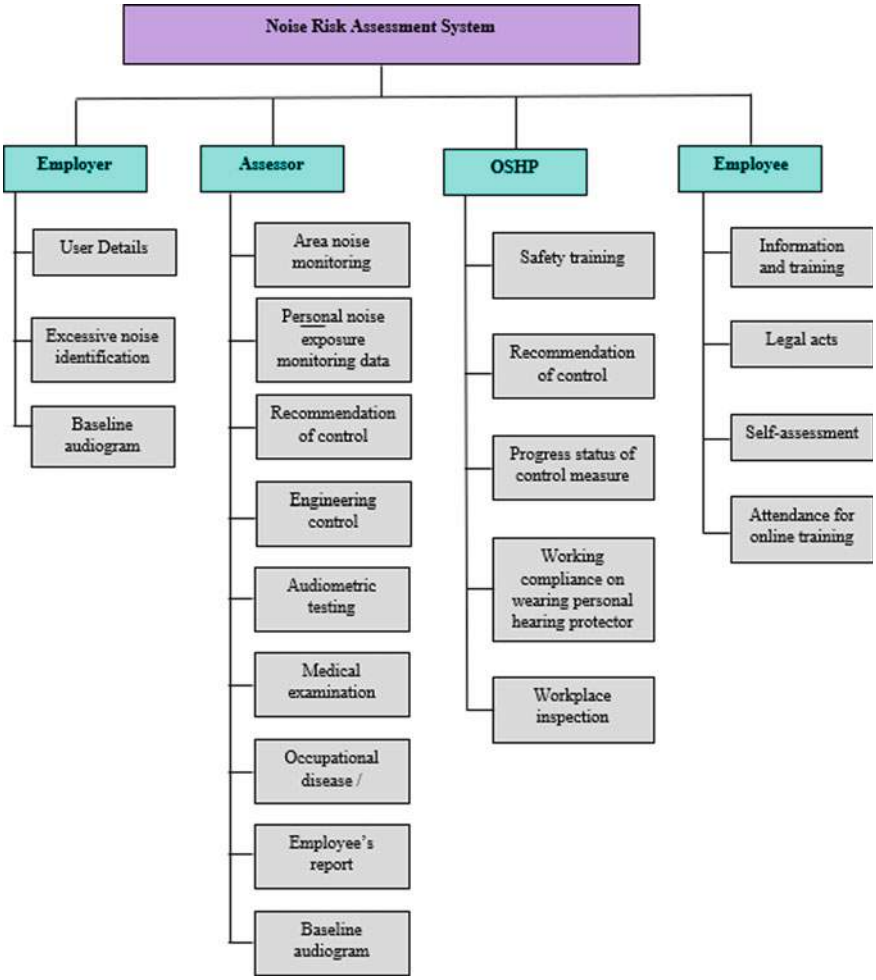

Fig. 1 Framework of noise risk assessment and management system

2.4 Expert Validation

Two experts were involved in validating the system. The expert panels were among the safety and health manager and noise risk assessor. The expert panels reviewed the content of the prototype system. The experts were given an evaluation form to complete after evaluating the developed prototype system. The expert panels provided their comments on the system's content and suggestions for improving the system.

Table 1 Curved grading scale [7]

Grade	SUS
A+	84.1–100
A	80.8–84.0
A−	78.9–80.7
B+	77.2–78.8
B	74.1–77.1
B−	72.6–74.0
C+	71.1–72.5
C	65.0–71.0
C−	62.7–64.9
D	51.7–62.6
F	0–51.6

3 Results and Discussion

3.1 Manual Documentation

The forms, tables and questionnaires on controlling noise risk are provided in ICOP for Management of Occupational Noise Exposure and Hearing Conservation 2019, along with a noise risk assessment form. The provided guide is used by most businesses to evaluate workplace noise. In order to identify occupational and nonoccupational risk factors for noise-induced hearing loss, respondents were questioned using a questionnaire in the research of self-assessment of hearing status and risk of NIHL in workers in a rolling stock facility [8].

3.2 Noise Risk Assessment and Management System

The newly created framework for managing and evaluating noise risk will make users and employers more methodical. All records pertaining to noise and employees can be kept at the system's back end, and the system can also be backed up at any moment. The data can be obtained after any harmful occurrence that the system may have been exposed to. Employers and assessors can save time by having employees view training materials related to noise on the system. Physical training can be cut back on, and businesses can save money using this technique. Employees can use their personal or company devices to access this system. This system will accept reports from OHD in soft copies, such as reports of medical examinations. This system will enable OSHP to apply safety measures at the workplace or work environment by minimising observational efforts.

Fig. 2 Excessive noise identification interface

3.3 Development of Noise Risk Assessment and Management System

3.3.1 Employer's Dashboard

Excessive Noise Identification

For excessive noise identification, all questions were used from ICOP for Management of Occupational Noise Exposure and Hearing Conversation 2019 (Figs. 2 and 3). The standard checklist is used to determine the noise hazard present at the workplace [9]. The employer, as the targeted end user, can use this checklist by ticking yes or no in the system that had been developed. The identification should be conducted at each work area at the workplace. According to the Department of Occupational Safety and Health [4], the noise risk assessment must be done if at least one item on the checklist is ticked as yes.

3.3.2 Assessor's Dashboard

Area Noise Monitoring

The noise assessor can fill up the interface for area noise monitoring (Fig. 4) in the work area of a workplace. The sound level meter (SLM) that is used and the reading from the SLM shall be recorded at this interface. It is possible to determine the colour zone from the reading noise mapping. To be clearer, an accurate dB value of the area noise does not measure an employee's exposure to noise. If an individual only works for a short time, a high area noise may not harm their health. The sources of noise that

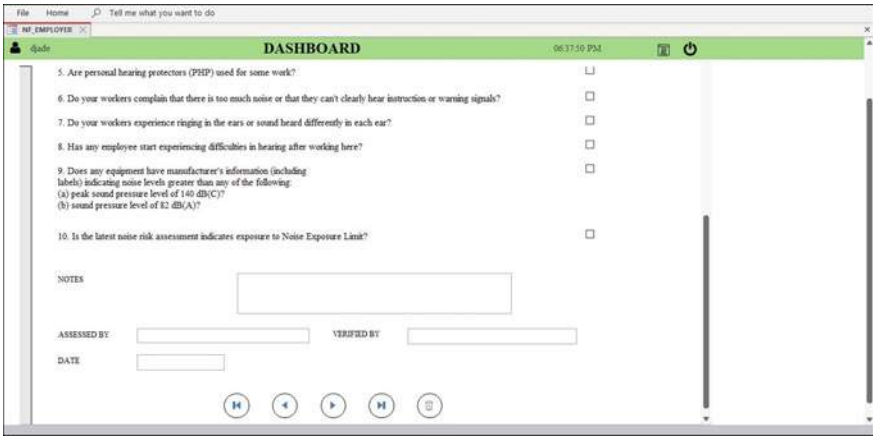

Fig. 3 Excessive noise identification interface

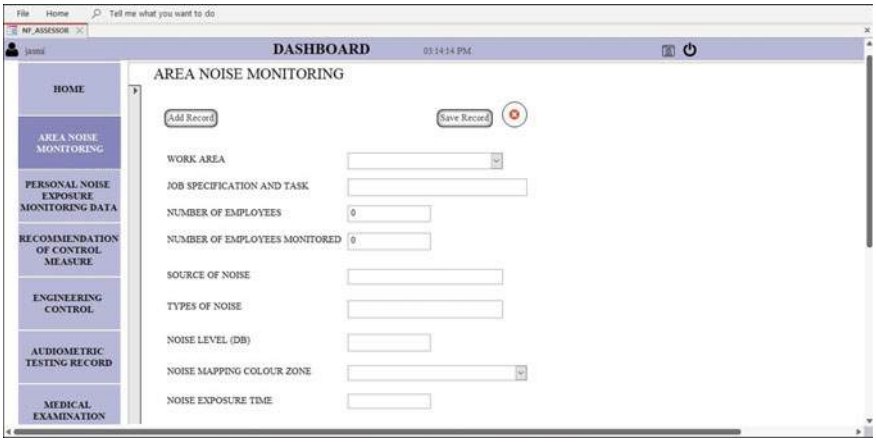

Fig. 4 Area noise monitoring interface

release sound for an extended period of time will be the focus of this area of noise monitoring. Personal noise exposure monitoring should be done to test employees for noise tolerance.

Personal Noise Exposure Monitoring Data

Figure 5 shows the personal noise exposure monitoring data interface. Personal noise exposure monitoring should be conducted for employees at the workplace during the working period. The personal noise exposure of each employee should be measured using a noise dosimeter. Employees must be grouped to determine similar group

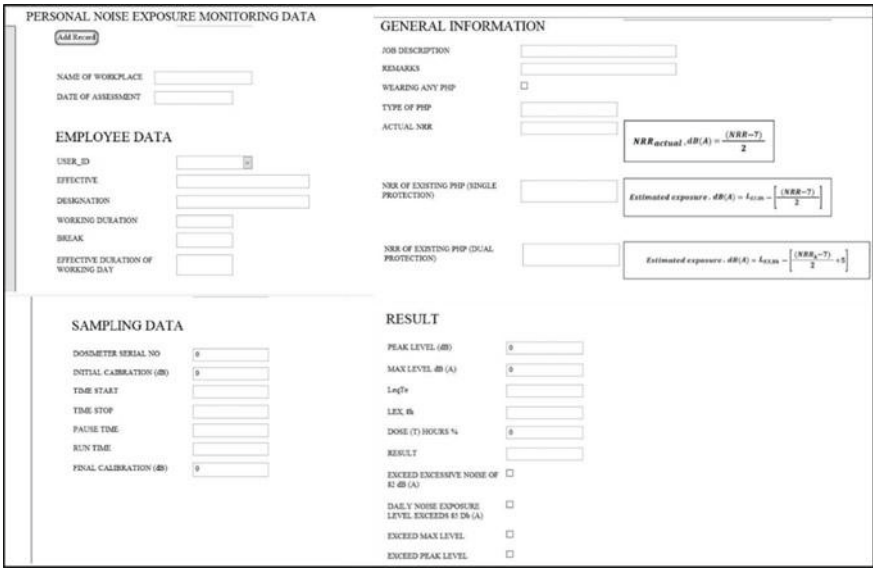

Fig. 5 Personal noise exposure monitoring data interface

exposure (SEG). After conducting the monitoring, the assessor can update all the information related to personal noise exposure into this interface.

Furthermore, the Noise Reduction Rate (NRR) information can be updated in this interface. Employees who wear just one PHP (earmuff or ear plug) will use the NRR for a single protection formula, while those who wear both PHP (earmuff and earplug) will use the NRR for a dual protection formula. Prior to calculating NRR for PHP, NRR actual needs to be calculated.

Recommendation of Control Measure

Figure 6 shows the recommendation of the control measure interface. The noise assessor can fill up the interface for the recommendation of control measures after conducting the personal and area noise monitoring. The noise assessor can suggest the best control measures to be implemented at the workplace. If the latest applied control measure is ineffective, the control measures will be evaluated and enhanced. Additional advancements will help to improve OSH overall if no new risks are added, and the current risk control mechanisms are always effective [9].

Audiometric Testing

Figure 7 represents the interface for audiometric testing. The audiometric testing report from Occupational Health Doctor (OHD) can be uploaded through this system.

Fig. 6 Recommendation of control measure

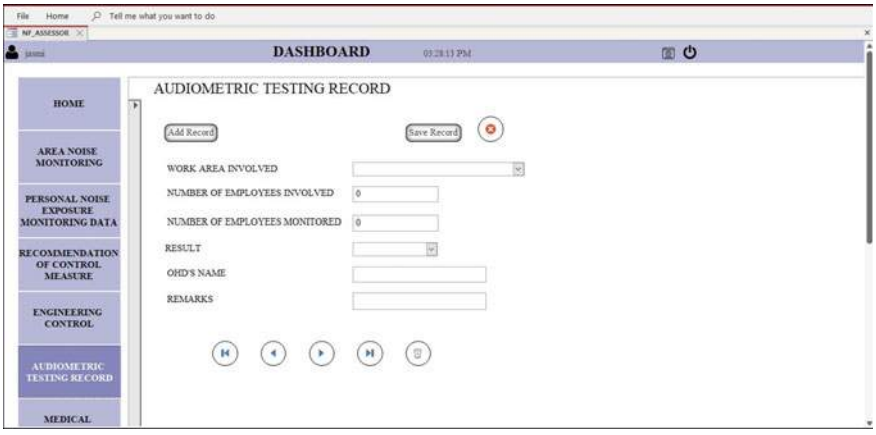

Fig. 7 Audiometric testing

The information included the name of the work area, the number of employees involved, the number of employees monitored, the result from the OHD and the OHD's name. According to Leonard [10], an employee's hearing is continuously monitored by audiometric testing. All personnel exposed to an action level of 85 dB or more over an 8-h TWA must be offered free audiometric testing by their employer. When test results are in doubt or related medical issues are considered present, the employee needs to be referred for additional testing. The employer shall refer the employee for a clinical audiological examination or anthological exam, as appropriate, if more testing is required or if the employer detects an ear pathology brought on by or made worse by hearing protection.

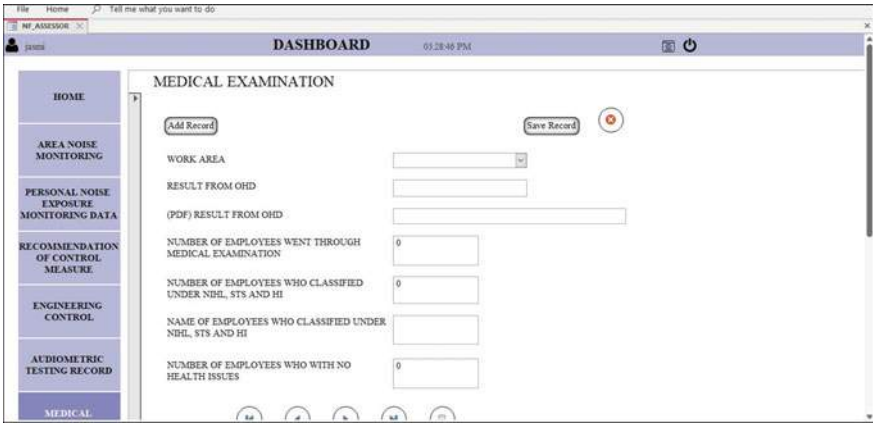

Fig. 8 Medical examination interface

Medical Examination

Figure 8 shows the medical examination interface. ILO (1998) stated that, when necessary, medical examinations should be conducted before or soon after employment or assignment to gather data and serve as a baseline for future health surveillance [11]. The medical exam should be performed with consideration for the possibility of enhancing working conditions through innovative work process design, ergonomic engineering, and the elimination of occupationally hazardous agents, or through their replacement or substitution with safer materials or techniques.

Occupational Disease/Poisoning

Figure 9 represents the interface for occupational disease or poisoning. Two tests will examine occupational disease/poisoning: Rinne and Weber test. They aid in identifying if an employee suffers from conductive, sensorineural, or mixed hearing loss. This will make it easier for OHD to decide whether or not to undertake a medical examination. The Rinne test compares bone conduction to air conduction to assess hearing loss [12]. The Weber test can find unilateral sensorineural and conductive hearing loss [13].

3.3.3 Occupational Safety and Health Practitioner Dashboard

Safety Training

Figure 10 shows the interface for safety training. They must receive safety training to protect employees' safety, health, and welfare at work. Physical training would

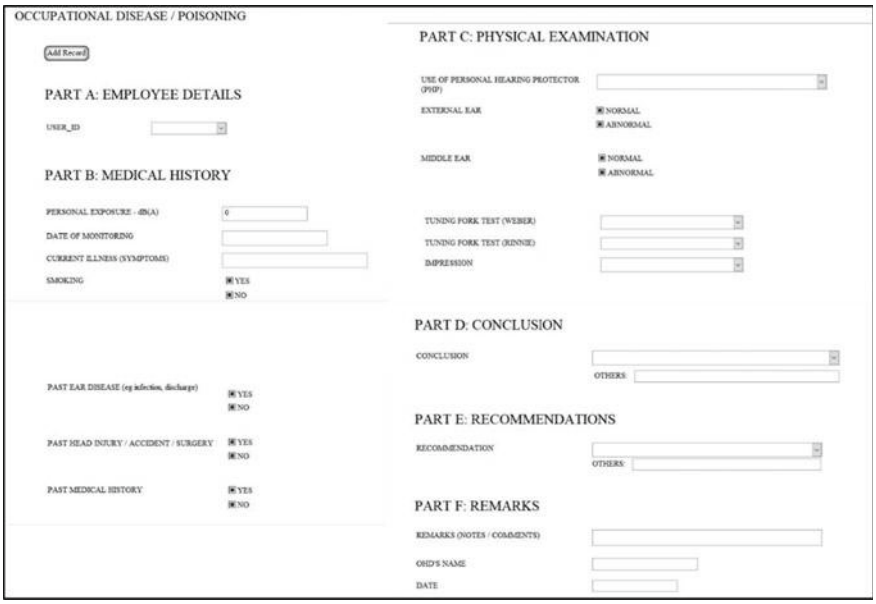

Fig. 9 Occupational disease/poisoning

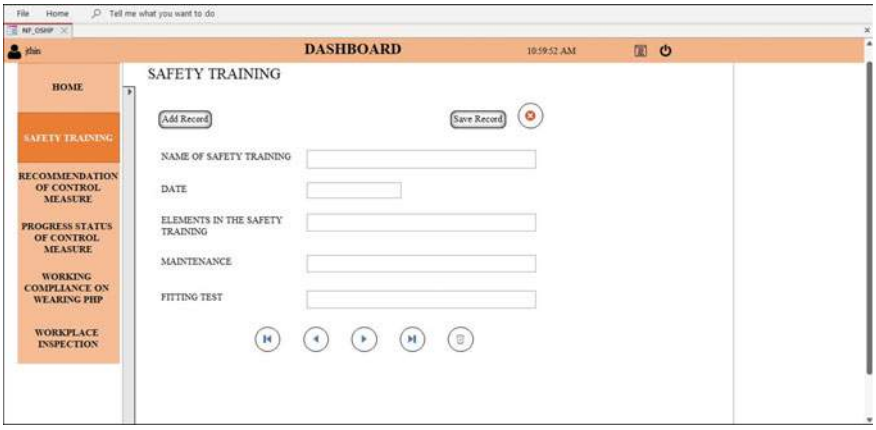

Fig. 10 Safety training

make up the majority of the training. This "safety training" section was developed to ensure that every training was recorded. Employees will receive fitting tests as part of their training to ensure the PHP is utilised correctly and implanted in their ears.

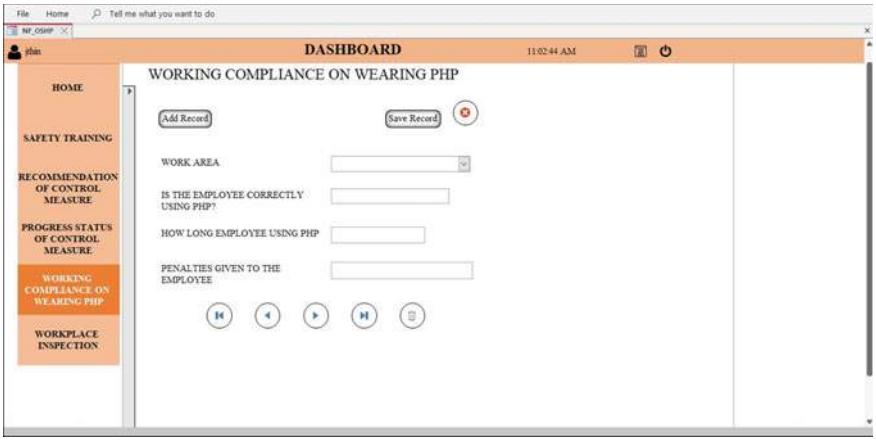

Fig. 11 Working compliance on wearing PHP

Working Compliance on Wearing PHP

Figure 11 represents the interface for working compliance on wearing PHP. Employees will receive PHP if there is a noise risk in their work area. This system will guide employees in choosing the type of hearing protection and offer more options to influence the wearing of hearing protectors. Most participants believe that personal discomfort is a factor in using hearing protectors at work; 36.2% report that wearing them makes their ears painful 49.1% report feeling uncomfortable, especially in warm weather, and 27.6% report itching [14].

Workplace Inspection

Figure 12 shows the workplace inspection interface. To ensure there are no workplace risks or hazards that could impact an employee's safety or health, OSHP will conduct an inspection there (Fig. 12). OSHP will update work instruction, safety operating procedure (SOP), result from audit, compliance level of employee to PHP and effectiveness of control measure in this system.

3.3.4 Employee's Dashboard

Information and Training

Figure 13 shows the information and training interface. It is crucial to give staff education and training. Without the right knowledge and instruction, personnel may do their duties competently, resulting in safety and health problems. The Noise Exposure Regulation 2019 has stated that employers are required to give staff training

Fig. 12 Workplace inspection interface

sessions at least once a year, instructions on how to use personal hearing protectors properly, and enough information about the effects of noise exposure on a person's hearing and the requirement to undergo an audiometric test [3] This system will offer online training for staff members in an advanced manner (refer Fig. 13). In a study on knowledge and compliance with standard precautions among undergraduate nursing students, there was a strong positive correlation between knowledge and compliance with standard precautions among the participants. In the areas of correct PPE use, a link between knowledge and compliance was specifically noted [15]. This demonstrates how having enough knowledge can result in employees acting appropriately, like by wearing appropriate PHP at work.

Self-assessment

The questionnaire for the identification of excessive noise was included in this self-assessment part (Fig. 14). The questions were modified so that employees could use them to answer. Employee self-assessment will enable the organisation or OSHP to assess and identify hazards and risks thoroughly. Its goal is to ensure that line management efficiently tracks operational safety performance and acts promptly to improve performance.

3.4 Validation and Usability of the Developed System

System Usability Scale Test

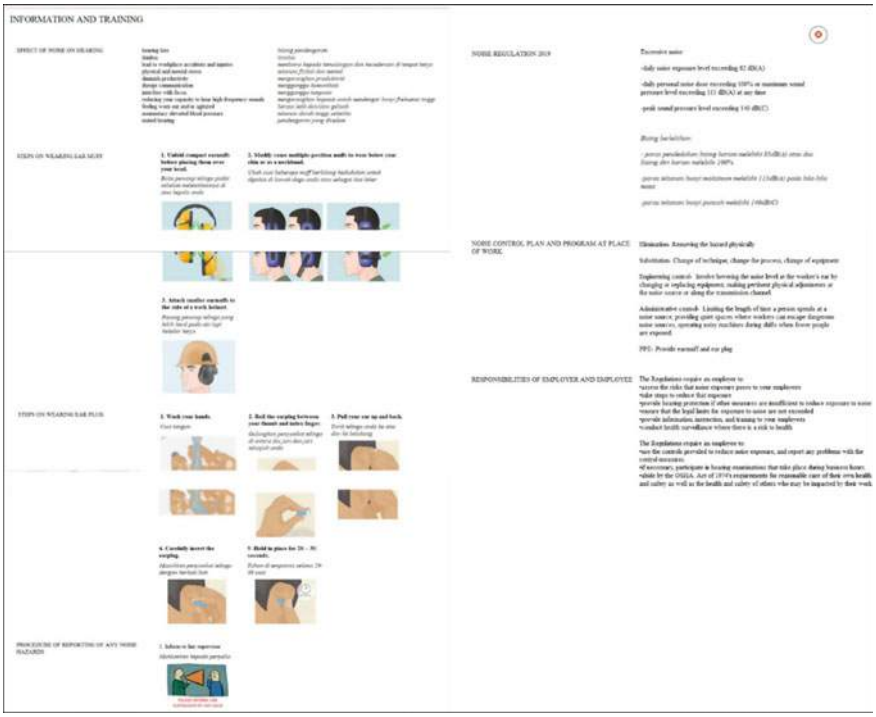

Fig. 13 Information and training

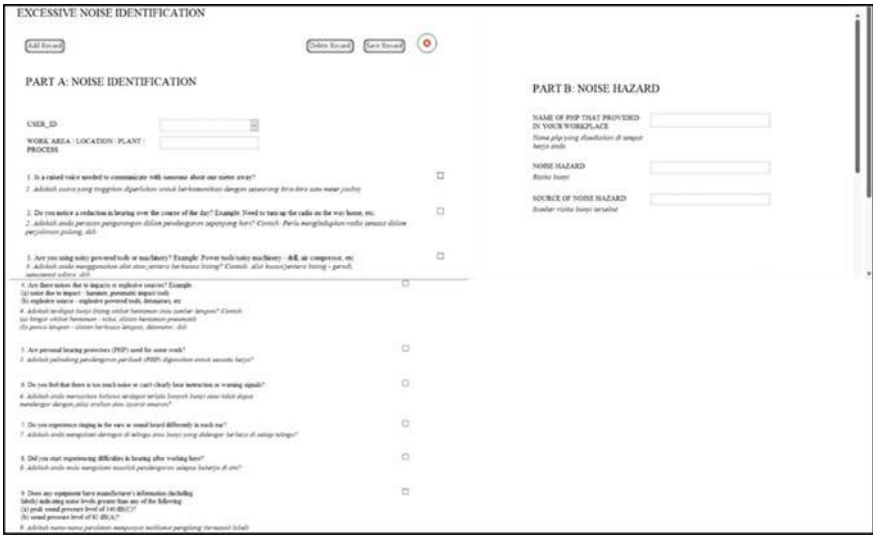

Fig. 14 Self-assessment

SUS questionnaires were involved among five (5) target respondents. The five respondents were among the targeted end user. Compared to custom-made and other commercially accessible questionnaires, SUS has been found to be more accurate and discover differences at smaller sample sizes [16]. The average SUS score obtained from the user rating for this developed Noise Risk Assessment and Management System is 75.5, which is grade B+ , as in Table 1. The grade is considered as good in adjective rating.

4 Conclusion

The two (2) appointed expert panels successfully validated the developed system. A system built for Noise Risk Assessment and Management demonstrated that it is suitable for usage in the industry. Using this system, noise risk in the industry may be addressed systematically since it integrates the Usability of the employer, noise risk assessor, occupational safety and health practitioner, and employee. All important information and data needed to manage workplace noise were synthesised, which can be executed by a database system. This developed system will be beneficial to both parties, employers and employees while the one developed by NIOSH which is NIOSH Sound Level Meter (SLM) app was only focused on testing noise levels in the workplace, making informed decisions about noise exposure, and prevent occupational hearing loss.

A mobile application version of the Noise Risk Assessment and Management System may be developed for future research or study. The newly developed system requires additional security elements so that there is no possibility of a bypass between the dashboards. It is necessary to incorporate videos and more infographics into the system for the users.

Acknowledgements The authors would like to thank the Universiti Malaysia Pahang, Malaysia, for providing financial support under Internal Research grant RDU190388 and RDU210334.

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