Journal of Occupational Safety and Health

June 2019 **Vol. 16 No. 1**

Contents

Introducing the Journal of Occupational Safety and Health

The National Institute of Occupational Safety and Health (NIOSH) is delighted to announce the publication of Journal of Occupational Safety and Health (JOSH).

JOSH is devoted to enhancing the knowledge and practice of occupational safety and health by widely disseminating research articles and applied studies of highest quality.

JOSH provides a solid base to bridge the issues and concerns related to occupational safety and health. JOSH offers scholarly, peer-reviewed articles, including correspondence, regular papers, articles and short reports, announcements and etc.

It is intended that this journal should serve the OSH community, practitioners, students and public while providing vital information for the promotion of workplace health and safety.

Apart from that JOSH aims:

- To promote debate and discussion on practical and theoretical aspects of OSH
- To encourage authors to comment critically on current OSH practices and discuss new concepts and emerging theories in OSH
- To inform OSH practitioners and students of current issues

JOSH is poised to become an essential resource in our efforts to promote and protect the safety and health of workers.

From the Editor in Chief

Workplace safety is of paramount importance. Much needs to be done to encourage employees, employers and industries to place occupational safety and health at the top of their agenda. Our commitment to initiate and to ensure the vital changes are in motion are imperative to ensure that safety is at the forefront of everyone's thoughts bearing in mind that the commitment from management plays an integral role in Occupational Safety and Health.

The Journal of Occupational Safety and Health (JOSH), the inaugural edition to be published in Malaysia, aims to uplift awareness on safety and health at the workplace.

I would like to emphasize in no uncertain terms on The Potential of Blockchain Technology for OSH Management System. Malaysian industries are entering a period of major disruption rendered by new technologies such as Artificial Intelligence, Robotics, Blockchain, Nanotechnology as well as Building Information Modelling (BIM) and the Internet of Things (IoT). There are numerous benefits and challenges of implementing Blockchain technology in OSHMS and we reckon the technology can be achieved via the participation and involvement from each and every industry.

We aspire that the contents of the journal will be read and reviewed by a larger audience hence it will have a broader academic base, and there should also be an increased cumulative experience to draw on for debate and comment within the journal.

It is our hope that the journal will benefit all readers, as our purpose is to serve the interest of everybody across all industries. Prime focus will be on issues that are of direct relevance to our day-to-day practices.

I would personally like to take this oportunity to welcome all our readers and contributors to JOSH (Vol 16, No 1). I look forward to receive contributions from the OSH community in Malaysia and elsewhere for our next issues.

Ayop Bin Salleh
Editor-in-chief

June 2019, Vol. 16 No. 1

Review Article

Empowering Occupational Health Doctors through the Occupational Safety & Health (Noise Exposure) Regulations 2019

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ABSTRACT: *The Department of Occupational Safety and Health Malaysia (DOSH) is the authority responsible to safeguard the occupational safety, health and welfare of workers in Malaysia. Occupational noise-related hearing disorders are the leading type of occupational diseases recorded by DOSH every year. Occupational Health Doctor (OHD) is a competency recognized by DOSH and their scope of duties in industries is currently confined to conduct medical surveillance for workers with hazardous chemical exposure and confined space medical fitness examination. The duties of OHD are good to be expanded by empowering more of their roles in industrial activities involving other legislations under DOSH. The noise exposure regulation under the Factories and Machinery Act (FMA) 1967 has been governing the worker's exposure to hazardous industrial noise and preventing noise-induced hearing loss (NIHL) since 1989. However, the provisions of the regulation need to be strengthened in some essential medical elements of the Hearing Conservation Programme (HCP) for a comprehensive prevention of NIHL at the workplace. Recently enacted Occupational Safety and Health (Noise Exposure) Regulations 2019 offer a wider coverage of workers in ten sectors of industries applicable under the Occupational Safety and Health Act (OSHA) 1994. The current regulatory requirements for management of workplace noise have many improvements compared to the existing law. Enhancement in the medical requirements of industrial audiometry is made prominent by involving OHDs to interpret audiograms and conduct medical examination for workers. The reporting of occupational noise-related hearing disorders to DOSH is outlined better in the new regulation. The occurrence of NIHL and other related hearing disorders are expected to reduce eventually after the introduction of Occupational Safety and Health (Noise Exposure) Regulations 2019. The OHDs will play a pivotal role in industrial audiometry and prevention of hearing disorders among the working population.*

Keywords – *Occupational Safety and Health (Noise Exposure) Regulations 2019, OHD*

1.0 INTRODUCTION

Noise which is defined as unwanted sound is the leading occupational hazard in industries worldwide. The health effects of noise may vary from auditory damages to other non-auditory problems, posing social and economic burden to a country. Legislations for managing noise at work are important to protect the working community against the adverse effects of noise. Progressive improvements in existing laws and regulations related to noise at work, ensure that the current developments in occupational hygiene and health aspects of noise management are taken into account in workplace safety and health policies.

2.0 DOSH AND OCCUPATIONAL SAFETY AND HEALTH IN MALAYSIA

The Department of Occupational Safety and Health (DOSH) under the Ministry of Human Resources is the government agency responsible to ensure the safety, health and welfare of the workforce in Malaysia. The department's objective is to minimize industrial accidents and occupational diseases by the year 2020 through: (a) Reduction in the rate of fatalities to 4.36 per 100,000 workers; (b) Reduction in the rate of accidents to 2.53 per 1000 workers; and (c) Increase in reporting of occupational diseases and poisoning among workers by 30% as enshrined in the Occupational Safety and Health Master Plan 2016-2020 (OSHMP 2020). The strategies and programmes under OSHMP 2020 are shown in Fig. 1. DOSH focuses in standards: setting, enforcement, promotion and other activities related to the field of occupational safety and health (OSH). Studying OSH policies, drafting and amending related regulations, guidelines and Industrial Codes of Practices (ICOP) are some of the core activities under the standard settings services by DOSH.

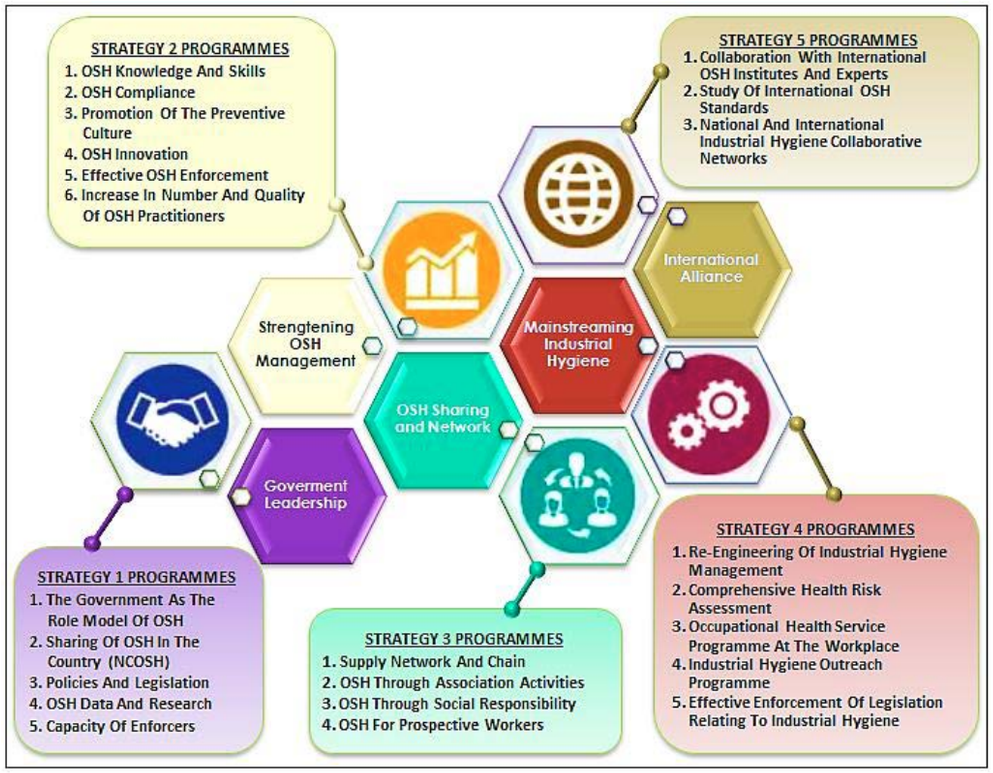

Figure 1 OSHMP 2020 Strategies and Programmes

3.0 BURDEN OF OCCUPATIONAL NOISE-RELATED HEARING DISORDERS

Hazardous industrial noise remains a significant problem globally. It is estimated that 9 million workers are exposed to 85 dB(A) and above time-weighted average level of noise in the United States. Seventeen studies conducted in 12 countries in South America, Africa, and Asia have revealed high occupational noise exposures with reported cases of hearing losses. Occupational noise causes 16% of disabling hearing loss in adults (more than 4 million disability-adjusted life years; DALYs), ranging from 7% to 21% in various subregions.

The Occupational Health section of DOSH conducts investigations on industrial incidents and manages occupational disease reports in Malaysia. Overall, the number of occupational diseases and poisonings recorded by this section are in an increasing trend significantly after the introduction of the OSH (Notification of Accident, Dangerous Occurrence, Occupational Poisoning and Occupational Disease - NADOPOD) Regulations 2004 and Occupational Safety and Health Master Plan 2015. However, the increase in awareness among employers and occupational health practitioners as well as the mushrooming number of industries with new-emerging industrial hazards may not be denied as factors contributing to this trend of increasing occupational diseases and poisonings.

As for the consequences of industrial noise, occupational noise-related hearing disorders (HD) have been contributing to more than 60% of the total recorded cases for the past decade. Cases of noise-induced hearing losses, hearing impairments and permanent shifts in hearing thresholds of workers (permanent standard threshold shifts - PSTS) due to industrial noise constitute these occupational noise-related hearing disorders. In 2017, there were 2478 cases (88%) of HD recorded, followed by occupational musculoskeletal diseases (OMSD), 126 cases (5%) and occupational skin diseases, 69 cases (2%). The trend of overall occupational diseases and poisonings compared to HD from 2008 till 2017 are shown in Fig. 2. The detailed type of diseases recorded in 2017 are shown in Fig. 3. Occupational diseases and poisonings by sectors revealed that the manufacturing sector recorded the most number of cases in 2017, a total of 2431 cases (86.5%). This is followed by the mining and quarrying sector, 97 cases (3.5%) and the public services sector with a total of 88 cases (3.1%). Industries manufacturing rubber and plastic products, fabricated and basic metal products, food products and beverages and textile industry reported high numbers of HD.

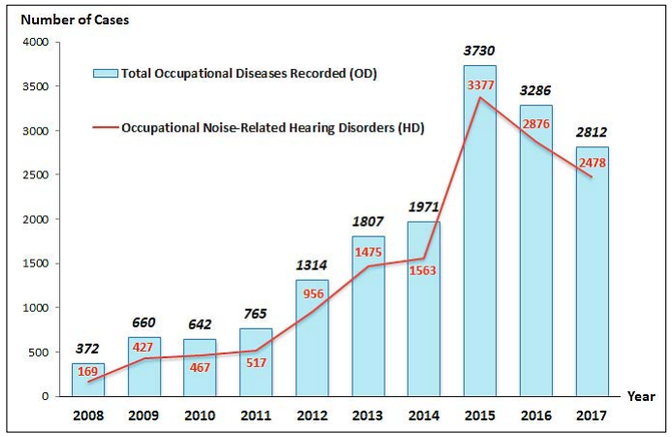

Figure 2 Trend of Overall Occupational Diseases & Poisonings and Occupational Noise-Related Hearing Disorders, 2008 – 2017, DOSH Malaysia[a]

[a] Based on progressive investigation of cases as of April 2019, data may vary depending on the time of analysis

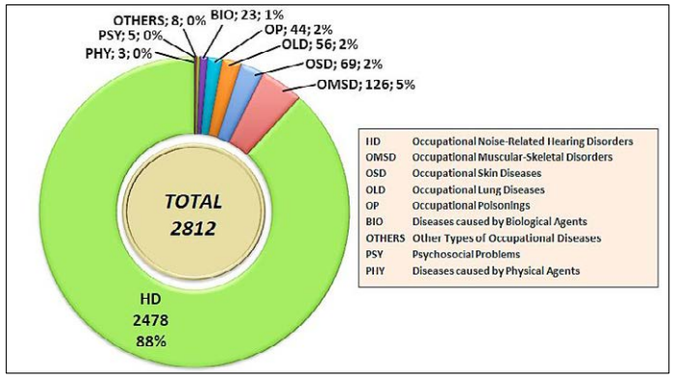

Figure 3 Occupational Diseases & Poisonings, 2017, DOSH Malaysia[a]

[a] Based on progressive investigation of cases as of April 2019, data may vary depending on the time of analysis

4.0 OCCUPATIONAL HEALTH DOCTOR AS A COMPETENT PERSON

Occupational Health Doctors (OHD) are medical practitioners whom had successfully completed a formal training in the field of occupational health. They are registered as a competent person with the Director General of DOSH to carry out medical surveillance programme for workers. There are many universities and training institutions conducting OHD or equivalent qualification training in Malaysia. The National Institute of Occupational Safety and Health (NIOSH) produce the most number of OHDs in the country every year.

OHDs' role was first recognized since the introduction of the Use and Standard of Exposure of Chemicals Hazardous to Health (USECHH) Regulations 2000 under the OSHA 1994. Their scope of duty was further expanded after the introduction of the ICOP's for Safe Working in the Confined Space in 2010. Under this ICOP, the employers of industries must ensure that its authorized confined space entrant person intending to work in confined space is certified medically fit by an OHD biennially. However, the OHDs role in industries was not prominent and appeared to be limited to medical surveillance and health examination for the purpose of fitness to work in confined space.

At present, there are a cumulative total of 1085 OHDs registered with DOSH and 871 doctors out of these registered OHDs are actively involved in delivering occupational health services particularly in USECHH medical surveillance and confined space health fitness examination. Most of these OHDs are practicing around the central region of Malaysia and in the heavily industrialised states of Selangor, Kuala Lumpur and Johor.

5.0 OVERVIEW OF LEGISLATIONS RELATED TO NOISE AT WORK IN MALAYSIA

In term of legislations under the purview of DOSH, comprehensive protection of the working population against the damaging effects of noise at work started after the introduction of the Factories and Machinery (Noise Exposure) Regulations 1989. The primary objective of this regulation is to prevent occupational noise-induced hearing loss (NIHL). The regulation outlines the legal obligations of employers as well as employees. The employers must not expose any of his employees to noise above the permissible exposure limit (PEL) - equivalent continuous sound pressure level of 90 dB(A); maximum sound pressure level of 115 dB(A) at any time and peak sound pressure level of 140 dB. Other responsibilities of the employers are to conduct noise exposure monitoring at the workplace, reduce noise exposure by either engineering, administrative or combined methods of control (as far as practicable), provide approved hearing protective devices to their employees, establish and maintain an audiometric testing programme, provide employees with information and institute noise-related training programme at least once in every two years at their premises.

The regulatory requirements of the noise exposure regulation under the FMA were in line with the Hearing Conservation Programme (HCP), a well-known systematic programme implemented in most major industries to prevent NIHL and tackle issues arising from noise at work. However, some of the HCP elements were not adequately addressed in the FMA noise regulation. Medical evaluation and referral for instance is not prominent in the FMA noise regulation. Registered medical practitioners are expected to conduct medical examination only to establish a diagnosis of PSTS. Requirement for specific noise management policy is often misunderstood as general occupational safety and health policy at work by the employers. Nevertheless, this noise exposure regulation served as the only important legislation since 1989 to control employees' noise exposure at work with requirements for health surveillance in the form of periodic audiometric testing. DOSH has produced many guidelines and directive letters to increase industrial compliance to this regulation, one of them is the Guidelines for Control of Occupational Noise which was published in 2005.

6.0 OVERVIEW OF OCCUPATIONAL SAFETY & HEALTH (NOISE EXPOSURE) REGULATIONS 2019

The Factory and Machinery (Noise Exposure) Regulations 1989 which has been in operation for 30 years was gazette under the Occupational Safety & Health Act (OSHA) 1994 as OSH (Noise Exposure) Regulations 2019 on 1st March 2019. This regulation is expected to be in force from June 2019. It will be accompanied by an ICOP on management of workplace noise, a legally-bonded document to serve as a reference for industries to comply with the regulation's requirements. The primary role of the regulation and ICOP is to reduce the occurrence of occupational noise-related hearing disorders especially NIHL.

As the new noise regulation was promulgated under the OSHA 1994, the major advantage is that all ten sectors covered under the OSHA 1994 will be applicable to this regulation as well. Thus, the protection of the working population against hazardous noise are being widely expanded under this regulation. This regulation, similar to the OSHA 1994, is not

applicable for work on board ships governed by the Merchant Shipping Ordinance 1952, the Merchant Shipping Ordinance 1960 of Sabah and Sarawak and the armed forces. Other important changes in the regulation are related to the requirements for noise risk identification, audiometric testing, medical evaluation, reporting of HDs and training. The key elements of OSH (Noise Exposure) Regulations 2019 are explained in Table 1 below.

Table 1 Key Elements of OSH (Noise Exposure) Regulations 2019

Essential Definitions
• Excessive noise : daily noise exposure level >82 dB(A), daily personal dose > 50%, maximum sound pressure level > 115 dB(A) at any time or peak sound pressure level > 140 dB(C)
• Abnormal audiogram : an audiogram that shows a hearing loss, hearing impairment or PSTS
• Medical Examination : an examination that includes history taking, physical examination and other relevant investigations to diagnose or rule out any occupational or non-occupational auditory disorder
Excessive Noise Identification
• Mandatory for employers to identify employees exposed to noise at places of work using methods determined by the Director General (DG) of DOSH • Employer to conduct review identification if: - there is change in the machinery, equipment, process, work, control measures or operation in which any employee may be exposed to excessive noise; - not more than 1 year after previous identification ; or - directed by the DG DOSH
Excessive Noise Risk Assessment
• Employer to appoint Noise Risk Assessor (NRA) registered with DOSH to carry out assessment if identification reveals employee exposed to excessive noise • NRA to use equipment complying with the standard determined by the International Electrotechnical Commission (IEC) for noise risk assessment at the workplace • Noise risk assessment report submission by the NRA to the employer within 1 month • Employer to carry out NRA's recommendations of actions within 30 days • Employer to conduct review noise risk assessment if: - not more than 5 years from the last assessment; or - directed by the DG DOSH
Information, Instruction, Training & Supervision
• Provision of adequate information on effects of noise and audiometric testing by the employer to employees exposed to excessive noise • Employer to supervise control of noise exposure implementation at the workplace • Employer to conduct training on personal hearing protection to employees exposed to excessive noise at least once a year
Noise Exposure Limit (NEL)
• Occupational exposure limits: daily noise exposure level of 85 dB(A) or daily personal dose of 100%; maximum sound pressure level of 115 dB(A) at any time or peak sound pressure level of 140 dB(C) • Employer to reduce noise exposures of employees below NEL by engineering, administrative, combined method of control or by utilizing personal hearing protectors (hierarchy of control to comply with the principle of "as far as practicable") • Employer to ensure engineering control equipment are working good and efficient
Personal Hearing Protector (PHP)
• Employer to ensure PHP are always available, suitable, efficient, appropriately maintained and inspected • Employer to use PHP which will attenuate the employee's personal noise exposure reasonably below NEL (if properly worn) and approved by DG of DOSH
Hearing Protection Zone
• Areas with noise exposure exceeding NEL to be demarcated and properly marked with appropriate warning sign by the employer

• Employer to provide and ensure the usage of PHP in hearing protection zones
Audiometric Testing Program
• Annual audiometric testing at approved Audiometric Testing Centre (ATC) for employees exposed to NEL at no cost to the employee • Employer to establish baseline audiometric testing within 3 months of employee's exposure to NEL • Interpretation of audiogram by OHD appointed by ATC • Mandatory medical examination by OHD for employee with abnormal audiogram • Reporting of occupational noise-induced hearing loss, hearing impairment or PSTS by the OHD and employer to DOSH within 7 days • ATC to submit audiometric testing report to employer within 30 days • Employer to inform audiometric testing results to his employees within 21 days • Employer to carry out audiometry retest for employees with temporary standard threshold shift and implement measures to protect the employees' hearing from worsening • Provision and training in the use of PHP for employees with occupational noise-induced hearing loss, hearing impairment or PSTS
Recordkeeping
• NRA report for not less than 30 years • Audiometric testing report for as long as the employee is employed and 5 years after he ceases his employment • Transfer of NRA and audiometric testing records to the employer's successor • Notice to the DG of DOSH 3 months prior to the disposal of records and transmit the records to the DG of DOSH if requested
Penalty for Offence
• Fine not exceeding RM 10,000 or imprisonment for one year or both

7.0 MEDICAL PERSPECTIVE OF OCCUPATIONAL SAFETY & HEALTH (NOISE EXPOSURE) REGULATIONS 2019

Managing the impact of industrial noise from a medical perspective has been given crucial emphasis in the current noise exposure regulation. This includes the role of medical professionals and delivery of industrial audiometric services. Industrial Audiometric Testing Centres (ATC) are registered and monitored by DOSH to follow standard procedures in conducting audiometry. ATC's need to be appointed by employers to perform audiometric testing for their employees. A list of registered industrial ATC's are available in DOSH website.

The role of the registered medical practitioners in the past regulation has been taken over by the OHDs whom have a better understanding of workplace hazards and work-related illnesses. The responsibilities of OHDs are clearly defined in this regulation whereby OHDs, being appointed by the ATC are required to interpret audiograms of workers exposed to excessive noise and perform medical examination for workers with abnormal audiograms. Initial interpretation is to differentiate between a normal and abnormal audiogram. An abnormal audiogram shows hearing loss, hearing impairment or PSTS. A guide to determine such abnormal audiograms is published in the ICOP. Comprehensive medical examination comprising of worker's history taking, physical examination and relevant investigations are required to be conducted by OHD in order to diagnose or rule out any occupational or non-occupational hearing disorders. The purpose of mandatory medical examinations stipulated under the regulation is to increase the diagnosis validity of occupational noise-related hearing disorders by not merely depending on audiometric results. ATC's are required to submit audiometric testing reports to the employers within 30 days to avoid any delay in managing the risk of further hearing damage posed by the workplace noise hazard and reporting of HD to the DOSH.

The reporting of occupational noise-related hearing disorders is also standardized through the current noise at work regulation. Reporting requirements which was partly spelled out in the FMA (Noise Exposure) Regulations 1989 as well as the OSH (NADOPOD) Regulations 2004 are being collectively expressed under the current regulation. The employers and OHDs are independently responsible to report occupational-related NIHL, hearing impairment and PSTS to DOSH. The definitions for NIHL, hearing impairment and PSTS will follow criterias given in international standards published and described in detail in the ICOP. Some other roles of OHDs in terms of occupational noise health surveillance are to act as the front-liners in diagnosing occupational and non-occupational hearing disorders, referring an employee with hearing disorder to relevant medical specialty to establish a diagnosis or for further management if necessary, advising the employers on training

their employees in the use of personal hearing protectors and educating an employee with an abnormal audiogram on best practices to conserve his hearing from NIHL.

8.0 CONCLUSION

The current changes in the noise exposure regulation are expected to bring major impact at workplaces in terms of better control over industrial noise exposure and progressively reducing the occurrence of noise-related hearing disorders among the working population. The DOSH hopes that the OHDs will carry out their duties professionally under the new regulation and deliver their best services in the field of industrial audiometry. As the saying goes, "With great power, comes great responsibility", empowering OHDs in the field of occupational audiometry and prevention of NIHL will be accompanied by a huge responsibility shouldered by these OHDs. In the future, the Department also anticipates increasing the roles of OHDs in a more diversified delivery of occupational health services to the workforce in Malaysia. Safeguarding the safety, health and welfare of employees are a joint responsibility between the employers, employees, the government and other stakeholders including competent persons such as the OHD.

"A Safe and Healthy Future of Work" – World Day for Safety and Health at Work 2019, International Labour Organization (ILO).

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Original Article

The Adoption of 5S Practice and its Impact on Safety Management Performance: A Case Study in a University Environment

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ABSTRACT *The practice of 5S has been adopted by many organizations as a method to organize the workplace towards reducing waste and improving productivity. Moreover, the practice also promotes a safe and efficient environment in organisations. As safety performance of the workplace is among the key issues in most industries including universities to become world class organizations, this study seeks to address empirically the impact of 5S practice on safety management performance. In this context, a survey questionnaire is employed and distributed to 60 employees of the selected university to examine the employees' perception on the adoption of 5S practice as well as the impact of 5S practice towards safety management performance. The questionnaires were validated by a pilot test with an acceptable value of Cronbach's alpha. Overall findings highlight there was positive perceptions toward 5S practice among the respondents. The results also revealed that 5S Audit has a very strong positive correlation with safety management performance. Furthermore, 5S Training and Top Management Commitment were (2) factors that strongly correlated to safety management performance. These factors are highly important in contributing toward the success of safety management performance. Additionally, since most of the employees were not exposed with Occupational Safety and Health (OSH), this study reveals moderate negative correlation between compliance to OSH Requirements and safety management performance.*

Keywords – *5S Practice, Occupational Safety and Health (OSH), Safety Management Performance.*

1.0 INTRODUCTION

5S practice is often viewed as an effective method to increase efficiency and productivity. By reducing clutter, 5S also helps to create a safer and healthier workplace. This systematic process of housekeeping has been implemented not only in major industries in Japan, the practice is widely adopted in retail shops and even in their houses. The misperception of 5S practice; it is merely a housekeeping activity whereas it is a part of Visual Factory Management (VFM) and a system to reenergize the workforce. The implementation of 5S is considered as an important support to other manufacturing improvements such as, Just-in-time (JIT) or Lean Production, cellular manufacturing, Total Quality Management (TQM), or Six Sigma initiatives. It is also a great contributor to establishing a safer and better workplace (Grover, 2012).

Safety on the other hand is an integral part of the first three "S" in the 5S practice: Sort, Set in Order, and Shine, and the remaining two "S"; Standardize and Sustain are the methods used to ensure safe and good housekeeping are maintained. Organizations especially in small and medium enterprises (SMEs) believe that managing safety is trivial as they do not see the positive relationship between competitiveness and safety. Lee (2010) stated that in SMEs, safety and health are often viewed as counterproductive to the operation and never treated as a crucial part of the overall management of the organization. However, good occupational safety management can have a positive effect not only on accident rates, but also on competitiveness variables and financial performance (Fernández-Muñiz, Montes-Peón, & Vázquez-Ordáz, 2008).

In this study, 5S practice in the selected university has been implemented since 2014. From 2014 to 2017, the university has successfully obtained Quality Environment (QE/5S) Certification from Malaysia Productivity Corporation (MPC). The implementation involved all employees from all levels and departments. The university is offering programs related to engineering technology which involved hands on practices with handling tools, equipment and machineries. The courses enrolled by students are mostly conducted in the workshop and laboratory which exposed them to various types of hazards along with different level of risks. Therefore, this study aims to analyze staff perceptions towards the adoption of 5S practice in the university and to explore the impact of critical factors in 5S practice towards safety management performance.

2.0 LITERATURE REVIEW

A lot of studies have reported the benefits of 5S practice towards organizations, but most of the studies did not mention on safety performance and worker safety as a goal or an outcome of 5S (Ramesh & Ravi, 2016). Ramesh and Ravi (2016) also stated that it is difficult to analyze the real relationship between worker safety and 5S implementation as improved employee safety is treated as an extra benefit and not the actual reason for 5S implementation. Fig. 1 shows the five pillars of the 5S concept with improved safety as one of its main advantage besides product diversification, higher quality, lower costs, reliable deliveries and high availability rate.

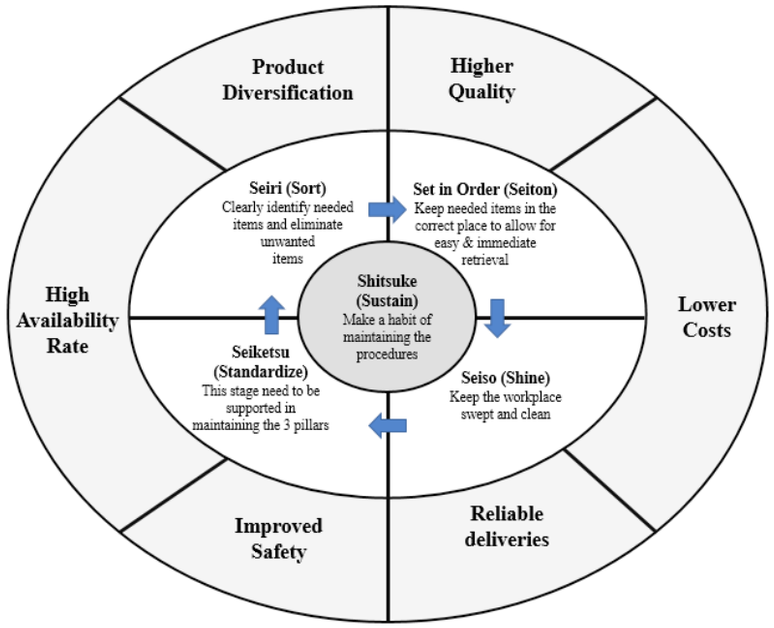

Figure 1 The Five Pillars of 5S Concept (Ramesh & Ravi, 2016)

5S practice was implemented in Boeing as a tool for the safety improvement process (Ansari & Modarress, 1997). In Boeing, 5S practice was pursued as a world-class strategy. Gapp et al. (2008) also emphasizes on the relationship of 5S with workplace safety and health. It is stated that maximizing the level of workplace safety and health is a primary objective of practicing 5S in conjunction with increased productivity. Pasale and Bagi's (2013) study has concluded that 5S practice is an effective management tool which can improve housekeeping, environmental conditions and safety and health standards. The study was conducted to study the 5S strategy for productivity improvement. Productivity can be optimized, and quality is improved by maintaining an orderly workplace.

Good workplace will help to not only prevent defects, it will also prevent accidents. In addition, Harea et al. (2018) have concluded that the 5S method implemented will not only increase an organizations' productivity, it will also create a safer workplace. Randhawa and Ahuja (2017), have conducted a research to evaluate the contribution of 5S implementation in Indian manufacturing industries. The findings have shown that the implementation of 5S benefited the organizations in terms of productivity, quality, safety, employee morale values, effective workspace utilization and cost optimizations.

Johana et al. (2014) conducted a study on the sustainability of 5S implementation in an administration office of a higher education institution. The study proved that the implementation of 5S is an effective way in providing a better workplace for the administration staff of the higher learning institution. With the implementation of 5S, the staff felt more comfortable, safe and organized which eventually improved their work quality.

The advantages provided by 5S practice are also in line with the Occupational Safety and Health Master Plan for Malaysia 2016-2020 (OSHMP 2020, 2016) main strategy which is to establish preventive culture in the workplace. This strategy was developed to transform the workplace in Malaysia into a safe and healthy environment to protect workers as the most important asset. A previous study conducted by Norhafizah et al. (2018) had focused on the effectiveness of the Occupational Safety and Health Master Plan 2015 (OSH-MP 15) in enhancing government leadership and preventive workplace. The study concluded that OSH practitioners and employers involved in the study were well informed with the program proposed by the government. Besides, the overall results also showed that they have been practicing good preventive culture in the workplace. This will be a good sign for the future of OSH Management System (OSHMS) in Malaysia as good OSHMS is proven to improve OSH conditions and support healthy and safe workplaces (Mohammadfam et al., 2017).

3.0 METHOD

3.1 Respondents

A sample size of 30 is held by many to be the minimum number of cases for research involving statistical analysis on their data (Cohen, Manion & Morrison, 2011). For this study, the researchers managed to distribute questionnaires to 60 academic and support staff randomly selected from academics and administration departments including workshops and laboratories area.

3.2 Data Collection and Instrument

Survey approach was employed where self-administered questionnaires were distributed. Survey method using distribution of questionnaire is the most effective technique to gather fast and accurate responses for this study as it helps the researchers obtain large number of responses quite quickly, which allows them to work with a lot of data (Cherry, 2018). The duration of each session was approximately 10 minutes. Researchers were available during the data collection process to answer inquiries by the participants. The survey questions were divided into five (5) sections:

- Section A: Respondent Information
- Section B: Adoption of 5S (Sort, Systematize, Sweep, Standardize, Sustain)
- Section C: Critical Success Factors;
  i. Top Management Commitment
  ii. Employee Involvement
  iii. Compliance with Occupational Safety and Health (OSH) Requirements
  iv. 5S Training
  v. 5S Audit
- Section D: Benefits of 5S Practice Towards Safety Performance

These questions were rated using 4-point Likert scale (1: Strongly Disagree; 2: Disagree; 3: Agree; 4: Strongly Agree). The use of middle scale (e.g. 3: Neutral) can cause the respondents to be undecided with the statements given in the questionnaire. Therefore, such a scale is eliminated in this study to avoid a central tendency bias. Central tendency bias (sometimes called central tendency error) is a tendency for a rater to place most items in the middle of a rating scale (Landy & Conte, 2009). The questionnaire was prepared in the English language.

3.3 Validity and Reliability Tests

3.3.1 Content validity

Three (3) academicians were selected to review the content of the questionnaire. The selected academicians are quality management and occupational safety and health field experts. Questions were edited to be appropriate and understandable by the participants.

3.3.2 Face validity

A pilot test was conducted with 30 staff, randomly selected from various departments for face validity and to test the reliability of the questionnaire. They are requested to identify any difficulties in understanding and answering the questions.

3.3.3 Reliability test

A reliability test was conducted to measure the stability and consistency of the measuring instrument. The respondents involved in the pilot test were required to answer all questions. The internal consistency was measured using the value of the Cronbach's alpha (α) for each item in the questionnaire, which is the most widely method used. Table 1 shows the accepted values of alpha (Sekaran, 2000).

Table 1 The Value of Cronbach's Alpha (α) (Sekaran, 2000)

Cronbach's alpha	Internal Consistency
α ≥ .9	Excellent
.9 >α ≥.8	Good
.8>α ≥.7	Acceptable
.7>α ≥.6	Questionable
.6>α ≥.5	Poor
.5>α	Unacceptable

3.4 Statistical Analysis

Descriptive and inferential statistical analysis were used to measure the variables in all sections to study the perception of respondents towards the implementation of 5S practice and its impact to safety management performance in the workplace. For Section A (Respondent Information), the data were analyzed through descriptive statistical method presented in a form of frequency and percentage. The data in other sections are presented in the form of mean.

Inferential statistical analysis was used to describe the relationship or variable variance through several statistical tests and thus generalize the results of the study (Cohen, 1977). In this study, the Spearman correlation test was conducted to identify the correlation between the independent variables (five critical success factors) and the dependent variable (safety management performance). Spearman rank correlation is a non-parametric test that is used to measure the degree of association between two variables. The correlations were tested using Spearman rank correlation where the test does not carry any assumptions about the distribution of the data and is the appropriate correlation analysis when the variables are measured on a scale that is at least ordinal.

Correlation analysis is often used by researchers to identify relationships and to determine the degree of strength of the relationship between the studied variables. The relationship between the studied variables is referred to as correlation, while the correlation strength in an analysis is represented by the correlation coefficient value (*r*). The stronger the association of the two variables, the closer the Spearman correlation coefficient, r, will be to either +1 or -1 depending on whether the relationship is positive or negative, respectively. For this study, the strength of the correlation is determined according to the size of the correlation coefficient proposed by Davies (1971) as shown in Table 2. The data were analyzed using IBM's SPSS 23.0 Software.

Table 2 Strength of correlation coefficient (Davies, 1971)

Correlation Coefficient Value (*r*)	Correlation Strength
0.70-1.00	Very strong
0.50-0.69	Strong
0.30-0.49	Moderate
0.10-0.29	Weak
0.01-0.09	Very weak

4.0 RESULTS

4.1 Face validity

The comments from all the respondents were taken into consideration. Most of the comments were positive which proved that the content of the questionnaire can be understood.

4.2 Reliability test

The results for the measurement of the questionnaire's internal consistency for the pilot test is shown in Table 3 below. It shows the value of Cronbach's alpha obtained for each variable involved in sections or subsections. The result shows that the internal consistency for all the variables are above acceptable level.

4.3 Respondent Information

The information of 60 respondents which involved their gender, age, job title, department and years of experience are shown in Table 4 below.

Table 3 Cronbach's Alpha (A) For Pilot Test

Section	Variable	Cronbach's alpha (α)
B	Adoption of 5S	0.888
C	Critical Success Factors	
	Top Management Commitment	0.951
	Employee Involvement	0.836
	Compliance with OSH Requirements	0.951
	5S Training	0.984
	5S Audit	0.925
D	Benefits of 5S Practice	
	Safety Performance	0.966

Table 4 Respondent Information

	Frequency (N=60)	Percentage (%)		Frequency (N=60)	Percentage (%)
Gender			**Department**		
Male	31	51.07	Academic	34	56.67
Female	29	48.30	Administration	26	43.33
Age			**Job Title**		
20-29	7	11.70	Lecturer	21	35.00
30-39	29	48.30	Technician	13	21.67
40-49	21	35.00	Executive	4	6.67
50-59	2	3.30	Officer	9	15.00
> 60	1	1.70	Administration Assistant	8	13.33
			Librarian	2	3.33
			Assistant Librarian	3	5.00

4.4 Descriptive Analysis

Table 5 depicts the mean value obtained for each variable. Mean values were obtained to study the perception of respondents towards 5S practice in the selected university, critical factors in its implementation and the effect of 5S practice towards safety performance. The mean scores for all variables were more than 3.00 which indicated that the responses were generally in the positive area except for "Compliance with OSH Requirements". It shows that most of the responses fall within the second scale to the first scale, which is between the "Agree" scale to "Strongly Agree" scale.

Table 5 Mean Value for Each Variable

Section	Variable	Mean
B	Adoption of 5S	
	Sort	3.37
	Systematize	3.38
	Sweep	3.33
	Standardize	3.40
	Sustain	3.33
C	Critical Success Factors	
	Top Management Commitment	3.23
	Employee Involvement	3.14
	Compliance with OSH Requirements	2.52
	5S Training	3.45
	5S Audit	3.01
D	Benefits of 5S Practice	
	Safety Performance	3.49

4.5 Correlation between Critical Success Factors in 5S Practice towards Safety Management Performance

Table 6 summarizes Spearman's correlation test results where the strength of the relationship represented by correlation coefficient, *r* between critical success factors in 5S implementation and safety management performance were identified. Based on the results shown in Table 5, all factors have significant relationship with safety management performance, where *p-value ≤0.01* for Top Management Commitment, 5S Training and 5S Audit; and *p-value ≤0.05* for Compliance with OSH Requirements and Employee Involvement. 5S Audit has a very strong positive correlation with safety management performance. Meanwhile, 5S Training and Top Management Commitment have a strong positive correlation with safety management performance. The other two factors; Employee Involvement and Compliance with OSH Requirements have moderate correlation with safety management performance.

Table 6 Correlation between Critical Success Factors and Safety Management Performance

Critical Success Factors	Correlation Coefficient (*r*)
Top Management Commitment	0.535**
Employee Involvement	0.316*
Compliance with OSH Requirements	-0.318*
5S Training	0.665**
5S Audit	0.705**

Note:
**Correlation is significant at 0.01 level (2-tailed)
*Correlation is significant at 0.05 level (2-tailed)

5.0 DISCUSSION

5.1 Descriptive Analysis

The results in Section B (Adoption of 5S) shows that staff were very committed in implementing 5S practice in the workplace. The mean values obtained for each step in 5S (Sort, Systematize, Sweep, Standardize, Sustain) were above 3.00 which indicated that the responses fall between "Agree" and "Strongly Agree". The implementation of 5S practice in the university has been a part of organizational culture since 2014 where the university successfully obtained the QE/5S certification from 2014 to 2017. Therefore, the staff perceived activities such as sorting unneeded item and cleaning the workstation as their routine. This result shows a positive development in the implementation of 5S in the university as 5S will not only improve the physical environment of the workplace, it will also improve the thinking processes of the workforce (Mohd Nizam et al., 2010).

The respondents' response in Section C (Critical Success Factors) were also positive. However, the results for 'Compliance with OSH Requirements' is rather low with mean value, $\mu = 2.52$. The respondents rated low score for the factor as most of the staff were not aware of OSH requirements. Safety and Health Executives with the support of the top management are putting their efforts to introduce the employees with OSH and the crucial elements in OSH. The first step taken was to establish a Safety and Health Committee that involves employees from various departments. Establishing good safety practice is one of the crucial factors in the implementation of 5S. A few examples of audit criterias related to safety management listed in the 5S checklist are the disposal of obsolete chemical substances or toxicants, the emergency exit labels, and cable management which refers to management of electrical or optical cable in a cabinet or an installation. OSH awareness is also important to ensure staff understand their rights and responsibilities in matters pertaining to safety and health at the workplace.

The result for mean value in Section D ($\mu = 3.49$) portrays that the staff strongly believe 5S practice has positive effects to safety management performance. They believe that 5S practice will create a safer, healthier workstation besides reducing the risks in the workplace. They also believe that awareness on workplace hazards will increased with the implementation of 5S. The results from a previous study conducted by Nahm et al. (2012) showed that 180 production workers in the Midwest of the USA supported the belief that lean management implementation success depends on the conducive mindset for lean management among production workers. Thus, employees' trust and positive perceptions have a crucial role in lean management implementation success. On the other hand, findings of previous studies also displayed a relationship between employee pessimism and poor safety performance (Oyan, 2000).

5.2 Correlation between Critical Success Factors in 5S Practice towards Safety Management Performance

5S Audit has a very strong positive correlation with safety management performance ($r = 0.705$). 5S Audit is an effective tool to identify room for improvement; which helps the organizations to analyze their strengths and weaknesses. It is categorized as a crucial tool to ensure accurate deployment of 5S in any organization (Ho, 1999b). As mentioned earlier, some of the audit criteria in the 5S Audit Checklist emphasizes on the element related to workplace safety, therefore the influence of 5S Audit towards safety management performance is indisputable.

Previous studies have identified the significant roles of 5S Training to ensure the success of its implementation (Mohd Nizam et al., 2010; Ablanedo-Rosas et al., 2010; Gapp, Fisher & Kobayashi, 2008). A research study conducted by Ghodrati and Zulkifli (2012) concluded that training is the key to 5S success. Without proper training, there will be a lack of capable workers thus it is nearly impossible to implement 5S. 5S Training was identified to have a strong positive correlation with safety management performance (r=0.665). Employees believed that 5S training has not only taught them the basic principles of 5S, the trainings also assisted them to get a clear understanding of the importance of an effective working environment. A conducive workplace will create a safer and healthier work environment with lower risk activities.

Top management commitment is another crucial criterion in the implementation of 5S. The results obtained show a strong positive relationship (r=0.535) between commitment by the top management and safety management performance. The commitment of top-level leaders is always considered as the biggest contributing factor to an organizations' success (Kheng & Lilis, 2018; Mohammadfam et al., 2017; Liu et al., 2015; Amiruddin et al., 2015). Leadership is placed at the center in a process-based quality management system model for ISO 9000:2015 standard. It shows that the commitment of top management is crucial for any type of improvement effort. To achieve long term success in safety performance, leadership engagement with senior managers are very crucial (Shang et al., 2011). As for 5S implementation, previous research by Ablanedo-Rosas et al. (2010) have concluded that obtaining the commitment from top management will help the workforce to face the challenges.

Employee involvement has a medium positive correlation with safety management performance (r=0.316). Like top management commitment, employee involvement is also considered as one of the biggest success factors for any type of improvement effort (Lilis, 2018; Al Manei et al., 2017; Kheng & Lilis, 2017; Hong et al., 2011). If the leaders successfully gather the staff to work towards achieving 5S objectives, the staff will also work hard to improve the performance of safety management.

The medium negative correlation (r= -0.318) obtained between compliance with OSH requirements and safety management performance has proven that the awareness of OSH among the staff in the university is quite low. Negative correlation between the two (2) variables indicated that one (1) variable increases as the other decreases, and vice versa. There is strong evidence that supported 5S practice as an effective technique that can improve housekeeping, environmental performance, as well as safety standards in a systematic way (O'hEocha, 2000). Therefore, this situation needs to be investigated further in future studies as compliance with OSH requirements is predicted to have a positive relationship with safety management performance.

6.0 CONCLUSION

5S is proven as an effective method to create a conducive workplace thus improving an organizations' efficiency, effectiveness, productivity and safety. Improving safety and health of the workers is usually not the main aim of 55 implementation in most organizations. However, various studies conducted on 5S implementation have shown the positive relationship between 5S practice and safety management performance. The findings that are presented in this study suggest that staff optimism towards the implementation of 5S in the workplace has established significant positive correlations between 5S practice and safety management performance. Despite the findings, it would be fruitful to pursue further research on identifying the significant relationship between 5S practice and safety management performance in different environments especially in the manufacturing industry where 5S is commonly being practiced. Future studies may also focus on the significant critical factors in 5S as the variables that affect the performance of safety management in organizations.

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June 2019, Vol. 16 No. 1

Original Article

Radon Concentration in Workplace Indoor Air

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ABSTRACT: *Radon exists naturally in the air. It can accumulate inside the buildings which may affect the indoor air quality. Radon is a radioactive gas that produces alpha particles during decay time. The alpha particles might cause harm to the human lungs and stomach. Inhalation of radon is one of the causes of lung cancer disease. Samples of inhaled radon in different rooms at the workplace were taken hourly through a passive diffusion chamber. The detection method was done using Alpha Spectrometry. The short term measurement was applied in the study to monitor the average weekly radon reading in different rooms in the Medical Imaging Laboratory of the University of Selangor (UNISEL). All tested rooms showed the existence of radon gas with different concentrations. Some of them showed the maximum reading of radon concentration which was higher than the radon action level of 148Bq/m^3 or 4pCi/l. Their weekly average of radon concentration is contributing almost 50% of the accumulated radon concentration in the laboratory. It is highly recommended that monitoring the concentration of radon in indoor air is performed to ensure it is at a safe and healthy level.*

Keywords - *Air, Indoor, Inhalation, Measurement, Radon*

1.0 INTRODUCTION

Radon exists inside the buildings which may affect the indoor air quality. It was found that different buildings may have different measurements of radon concentration (Mohamed & Marlia, 2018; Nisar et al., 2015). Radon is a natural radioactive element occurred in the form of gas, which emits alpha particles when it decays into Polonium. The alpha particles may cause harm to human organs such as lungs during breathing time or even to the stomach after drinking the contaminated water with radon. The possibility of radon causing harm to the lungs depends on the concentration level in the inhaled air. It was found that radon is the second cause of lung cancer after smoking (Nancy & Gary, 2018). The lung cancer risk increases when radon exposure is also increasing. The high concentration of radon in indoor air has a high considerable risk of lung cancer in the range from 3% to 14% (Hajo & Ferid, 2009).

Most of the Malaysian workers spend one-third of their day time at the workplace. It is very important to perform radon monitoring because there is a possibility of some workers may expose themselves to a high concentration of this radioactive gas (Martin et al., 2012). Some studies (Font et al., 2008; Espinosa et al., 2009; Rosabianca et al., 2012) showed that the average radon levels in underground workplaces are more than action level of 148 Bq/m^3 or 4 pCi/l as per recommended by the United States Environmental Protection Agency (EPA).

According to Health Facts 2017 report published by Ministry of Health Malaysia, the respiratory system diseases are the second highest cause of death in government hospitals after the circulatory system. There are many causes of respiratory system diseases, including radon inhalation. The aims of this study were to investigate the concentration amount of radon in the inhaled air at the workplace, to identify the rooms with a potential risk of having high concentration of radon, and to analyze any potential ways to avoid a high concentration of radon in indoor workplace.

2.0 METHOD

2.1 Room Specification

The samples of radon concentration in different rooms at Medical Imaging Laboratory of UNISEL Shah Alam's campus have been performed hourly using a passive diffusion chamber as per reference of study by Rydock in 2001 (Rydock et al., 2001). The Medical Imaging Laboratory is located at ground floor consisting of an x-ray room, darkroom, mammography room, lecture hall, two lecturer's rooms, and filing room. Fig. 1 represents the layout of the laboratory.

These rooms have different dimensions and specifications. The inner walls of x-ray and mammography rooms were built up from barium plaster. There is a window in the wall of lecturer's rooms while the mammography room, darkroom, filing room, X-ray room and lecture hall do not have any built-in window. The rooms have a door with different feature and design. The floor of the lecture hall is totally covered by carpet and the rest of the rooms are vinyl flooring. All rooms are equipped with the air-conditioning system except the filing room. Only darkroom has a fan type of ventilation device.

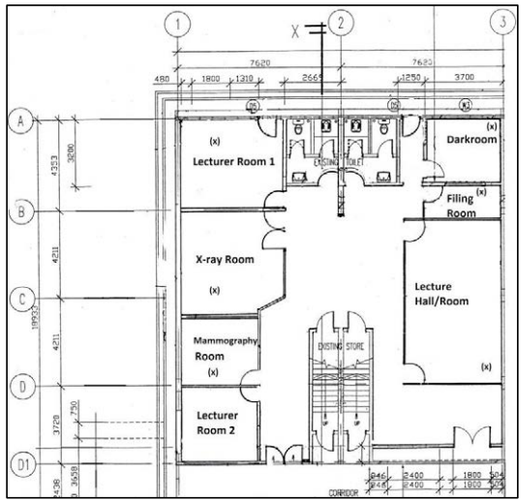


Figure 1 UNISEL Medical Imaging Laboratory Layout

2.2 Radon Detector

There are many types of detectors used to measure the radon level. Most of the detectors are used as a continuous radon monitor (Nisar et al., 2017). In this study, the Airthings Wave radon detector as shown in Fig. 2 was used to measure the amount of radon gas, temperature, and humidity in each room. Alpha Spectrometry is the method used to detect radon gas. The detector was placed at least 50 cm above floor level and at least 150 cm from the nearest door, window or ventilation device as recommended by the manufacturer. Its location inside each room is indicated as (x) in Fig. 1. The detector was placed at a breathing level height to make sure that the measured radon level represents the radon in an inhaled air. The amount of radon gas was monitored continuously for seven days, including weekends as per previous research study was done in 1998 (Mahat et al., 1998). The short-term measurement was applied in the study to monitor the average weekly radon reading and the maximum reading of radon.

Figure 2 Airthings Wave Radon Detector

3.0 RESULTS

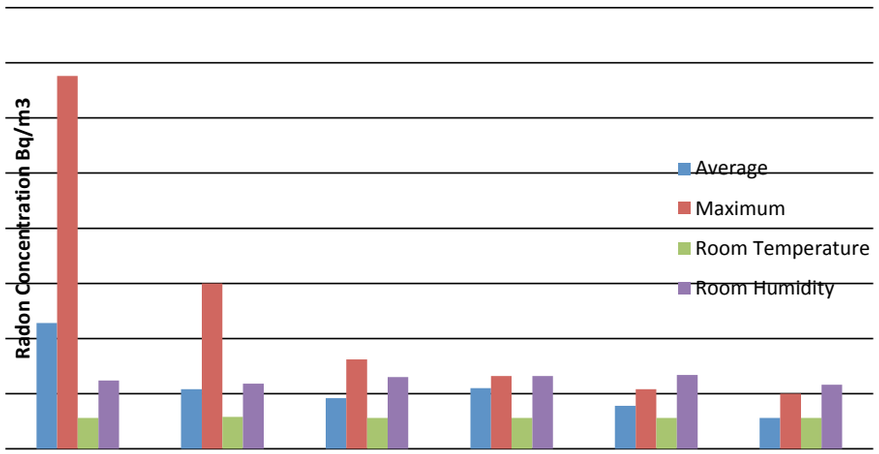
According to a study in 2011 by Chambers, it is useful to produce maps of the indoor radon level in order to identify its hazard (Chambers & Zielinski, 2011). Table 1 showed the existence of radon gas in all testing rooms. Each room had different values of radon concentration. Some rooms showed high concentrations of radon gas level while the other rooms maintained its value at a safe and healthy level.

There were no noticeable changes in room temperature. Most of the rooms maintain their temperature at 28°C. The room's humidity was maintained in the range of 55% to 70%. The highest room humidity was 66% which was measured in the lecture hall.

Table 1 Radon Concentration at Each Room

Location	Weekly Average Radon Reading Bq/m^3	Max. Radon Reading Bq/m^3	Average Room Temperature (°C)	Average Room Humidity (%)	Room Wall Barium Plastering	Room Window	Fan Type Ventilation Device
Mammography Room	114	338	28	62	Yes	No	No
X-ray Room	54	150	29	59	Yes	No	No
Lecturer's Room 1	28	50	28	58	No	Yes	No
Lecture Hall	55	66	28	66	No	No	No
Darkroom	46	81	28	65	No	No	Yes
Filing Room	39	54	28	67	No	No	No

The highest reading of radon concentration above the maximum level was in the mammography room as shown in Graph 1. Its maximum reading had reached 338 Bq/m^3. This reading represents the accumulation of radon gas over the weekend when the room's door was closed. Its value has gradually reduced to an acceptable safe level in the late evening of Monday when the door was totally open for the whole day that causes the radon to flow out of the room. Fig. 3 represents the process of radon accumulation and dissipation for the mammography room. In general, the monitoring of radon concentrations showed a lower radon concentration during working hours as compared to the day time (Sami & Riaz, 2015).



Graph 1 Maximum and Average Radon Concentration

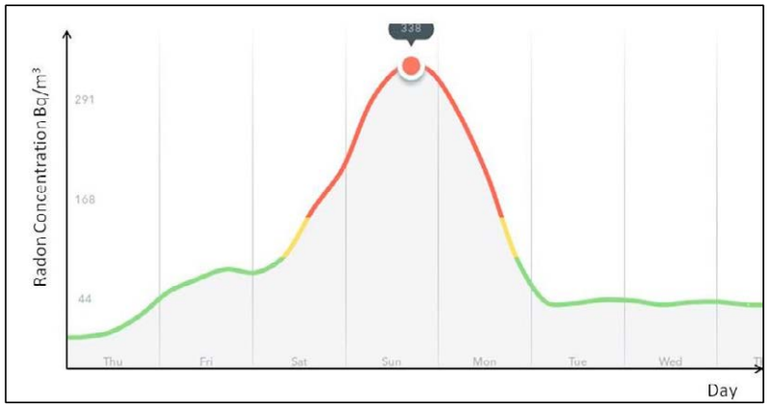


Figure 3 Radon Accumulation Graph for Mammography Room

The second highest maximum reading of radon concentration was in the X-ray room and its reading was 150 Bq/m^3. These two readings in mammography and x-ray rooms have maximum radon concentration more than radon action level of 148 Bq/m^3. The rest of the rooms showed the maximum radon concentration less than the action level. Their readings were measured below 100 Bq/m^3.

All rooms except Lecturer's room 1, have a weekly average radon concentration more than the worldwide average indoor radon concentration of 39 Bq/m^3 (Hajo & Ferid, 2009). Besides its maximum reading of radon concentration, the mammography room also has the highest weekly average radon concentration and its value is 114 Bq/m^3. It contributes almost 34% of the accumulated weekly average radon concentration in Medical Imaging Lab of UNISEL as shown in the chart of Fig. 4. X-ray room and lecture hall have similar average radon concentration of 16%. Darkroom showed less average radon concentration as compared to the X-ray and lecture hall. Subsequently, the Lecturer's room 1 showed a safe and healthy radon concentration. The previous Table 1 showed both Mammography room and the X-ray room have a combined weekly average radon reading of 168 Bq/m^3 that contributes 50% of the total weekly average radon reading of 336 Bq/m^3 in Medical Imaging Laboratory of UNISEL.

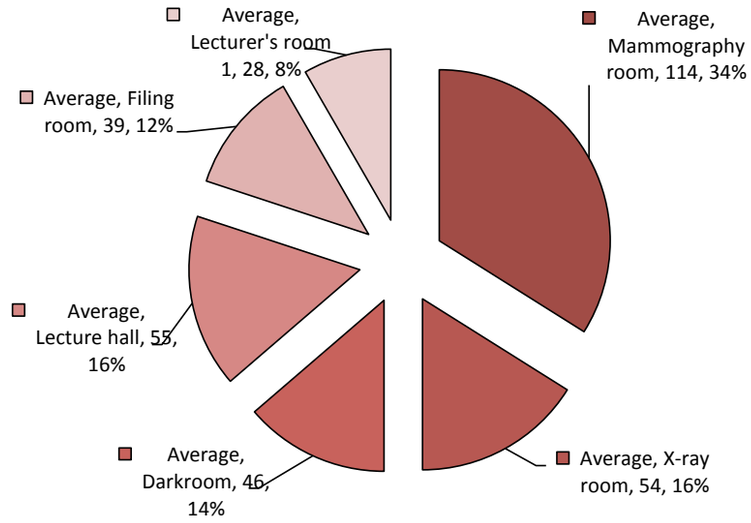


Figure 4 Percentage of Average Weekly Radon Concentration at Each Room

4.0 DISCUSSION

It was observed that the amount of radon concentration fluctuated over the measured time. There is no fixed value of radon concentration at selected locations or defined time. In general, the measurements can only give an idea regarding the level of radon during measuring time for a certain location.

The study showed that the room temperature does not have a significant role in maintaining the radon concentration. Most of the rooms had almost the same room temperature with different values of radon concentration. The percentage value of humidity in each room also does not have a direct relation to the radon concentration. Some rooms have almost the same humidity, but having different concentrations of radon.

The highest concentration of radon in Mammography and X-ray rooms is possibly because of the barium plaster coated wall. Radon gas is accumulated and trapped inside these rooms during the weekend time. It has less ability to flow out of these two rooms. There is a potential possibility to be exposed to high radon gas that exceeds 148 Bq/m^3 if someone is staying there for a long time over the next working day after the weekend break (Hajo & Ferid, 2009). This may induce any chances of getting respiratory disease related as illustrated in the AII process of Fig. 5.

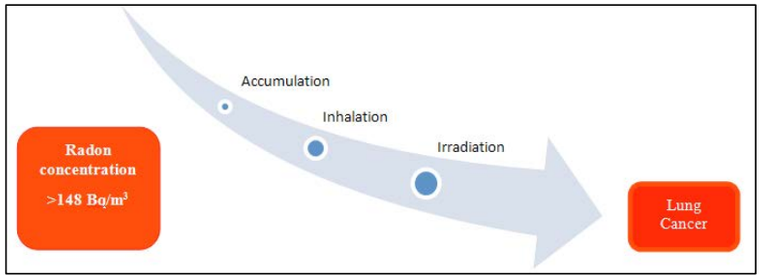


Figure 5 Process of Radon Cause Lung Cancer (AII Process)

The room size may affect the amount of radon concentration. The maximum and average radon concentration in Mammography room is more when comparing it to an X-ray room. It showed that the radon gas has the ability to be spread easily throughout the bigger size of the room.

The lecture hall with carpet flooring design had the average radon concentration almost the same as an X-ray room in the Medical Imaging Laboratory. It is possible that the carpet can trap the dust particles that may later become the source of radon gas.

The lowest amount of average radon concentration was recorded in the Lecturer's room 1. The dimension of the room is quite reasonable. It has a big size window and the room is located at the end corner of the laboratory. There is less possibility for radon gas to be accumulated in this room with high concentration and the mechanism of radon gas to flow out of the room is much easier and more practical.

5.0 CONCLUSION

Monitoring radon using basic conventional method is highly recommended to avoid any possibility of health risk caused by inhaled radon. It gives a significant finding regarding the concentration of radon in the indoor air to assure it is within the acceptable healthy level. It may also be applied to any rooms that have a possibility of containing a high concentration of radon. This study was carried out for prevention purposes to avoid any possible health risk caused by indoor radon concentration. For those rooms with a high concentration level of radon, it is most advisable to have safety features of the room and general guidelines to avoid high exposure to radon gas by implementing APP process as illustrated in Fig. 6.

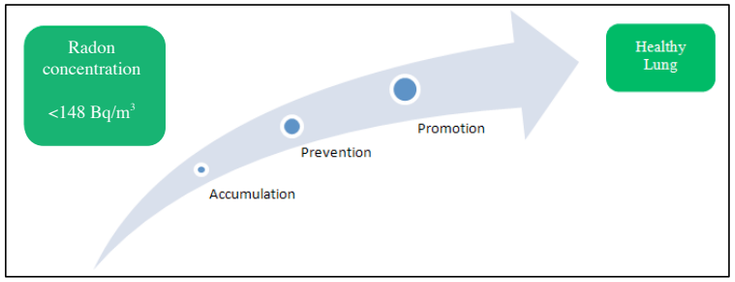


Figure 6 Prevention of Radon Exposure (APP Process)

ACKNOWLEDGEMENTS

This study is totally sponsored by UNISEL BESTARI RESEARCH GRANT under the project code (GPB/02-UNISEL17/ST-003) which was approved on November 2017 by Centre of Research and Industrial Linkages (CRIL), University of Selangor (UNISEL), Jalan Zirkon, A7/A, Section 7, 40000 Shah Alam, Selangor.

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Original Article

The Potential of Blockchain Technology for Occupational Safety and Health Management System

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ABSTRACT: *Industries in Malaysia are entering a period of major disruption caused by new technologies such as Artificial Intelligent, Robotics, Blockchain, Nanotechnology as well as Building Information Modelling (BIM) and the Internet of Things (IoT). In this fourth industrial revolution where information is generated and exchanged at a rapid and huge scale, its reliability is of paramount importance. The success of Occupational Safety & Health Management System (OSHMS) is highly dependent on the reliability of the information gathered and used, where a large number of intermediaries authenticate the information to establish trust between the stakeholders. Blockchain technology is able to do verification by virtue of secured distributed storage brings about a paradigm shift in the way we establish trust. This paper gives an overview of the potential use of Blockchain technology for Occupational Safety & Health Management System. The discussions focused on the benefits and challenges of implementing the Blockchain technology in OSHMS. The conclusion is drawn based on the strength in the characteristics provided by the Blockchain technology itself.*

Keywords – *Blockchain, Industry 4.0, Information System, Occupational Safety & Health Management System (OSHMS)*

1.0 INTRODUCTION

Industries in Malaysia are entering a period of major disruption caused by new technologies such as Artificial Intelligent, Robotics, Blockchain, Nanotechnology as well as Building Information Modelling (BIM) and the Internet of Things (IoT). In this fourth industrial revolution where information is generated and exchanged at a rapid and huge scale, its reliability is of paramount importance. The World Economic Forum (WEF) has highlighted that this revolution will have various impact on businesses, governments and individuals in driving the competitiveness and improving the quality of life of people (MiGHT, 2018). It also reported that a lot of initiatives have been taken by the government to adopt the Internet of Things and Artificial Technologies to prepare for the inevitable fourth industrial revolution. For example, an integration of information and communication technology (ICT) and smart policies for implementing smart cities vision. Both governments and private organizations need to collaborate for the future plan and have an insight into any changes that can occur all over the world.

In order to elevate the competitiveness of the country, Malaysia is looking at digital technologies and the way to interact with each other by increasing interest in this new technologies. Blockchain technology has been identified as a new enabler for the country in the private and public setting. In addition, it benefits the industries by offering trusted recordkeeping, shared trusted processes, improve discoverability and reduce costs and complexity. This paper discusses about blockchain technology which have several characteristics that could potentially be applied in the Occupational Safety and Health Management System (OSHMS).

2.0 BLOCKCHAIN TECHNOLOGY

Blockchain began to emerge in the public as one of the underlying technologies for the first cryptocurrency created as a counter model to the centralised authority (MiGHT, 2018). Technically, blockchain is a form of distributed ledger that stores information across multiple systems securely to empower any peer-to-peer transactions by creating intermediaries of trust. Blockchain is one of the most recent technology that is able to do verification by virtue of secured distributed storage that brings about a paradigm shift in the way we establish trust. Blockchain can be designed for different purposes such as automotive, financial services, healthcare and many others. Access to the blockchain platform is determined by the design of the platform whether it is a public or permissioned blockchain whereby the latter sets a specific requirement for participants to access. The important characteristics of blockchain architecture are as follows:

2.1 The blockchain platform

The core application of blockchain is a transaction database modelled as a secure ledger that is shared by all nodes or users of the blockchain system which acts as a highly transparent ledger. Transactions generally consist of a recipient address, a sender address, and a value (Pluralsight, 2017). A transaction changes the state of the agreed-correct blockchain that all nodes independently hold their own copy of the blockchain. New transactions are distributed throughout the network and independently verified and processes by each node. The movement of data within any blockchain architecture is established. Transactions contain one or more inputs and outputs. An input always references a previous transaction's output which allows for an uninterrupted, verifiable stream of values amongst addresses. The integrity and chronological order of the transactions are enforced by strong cryptographic rules.

2.2 Nodes in the blockchain

A blockchain system consists of a number of nodes and each node has a local copy of a ledger that belong to different users. As part of the network, the function of nodes is different which refer to their business intention. The nodes communicate with each other in order to gain agreement on the contents of the ledger and they do not require a central authority to coordinate and validate transactions (Technolab, 2018). As a trusted third party, all nodes maintains a fully replicated copy of a database in the blockchain system.

2.3 Network protocol

In blockchain technology, consensus protocols are one of the key elements and revolutionary features of the technology. These protocols create an irrefutable system of agreement between various devices across a distributed network, whilst preventing exploitation of the system (LISK, 2018). Consensus rules are considered for validating block and transaction within the network. The main requirement to achieve a consensus is an undisputed acceptance between nodes on the network. Consensus protocols are designed to be difficult to replicate by being extremely costly to carry out as a result of time, the requirement of computing resources required and the holdings of a particular cryptocurrency (LISK, 2018). The consensus method varies based on the validation of the block and forms of consensus. The effectiveness and efficiency of blockchain to function and exist relies on the consensus protocol. As a result, the information that is being stored is authentic and precise.

2.4 Transaction and Block

Both transactions and blocks are two types of blockchain implementation records. Transaction comprise the actual business data to be deposited in the blockchain while blocks record the sequence of transactions in the blockchain. Subsequently, the transaction is generated and pressed into the blockchain node network. This will be captured by a miner node to check and determine that the transaction is legitimate and served into a cryptographic hash function as represented to generate a unique string of digits and vitally combine them with other transactions. The generated hash is then stored with other metadata into a block. The block becomes the basis for running the hash function again to create a subdivision block.

3.0 BLOCKCHAIN CHARACTERISTICS

There are four fundamental characteristics of blockchain (Pattison, 2017) that causes it to be distinct and more transformative. The key characteristics is illustrated in Fig. 1 and explain as follows:

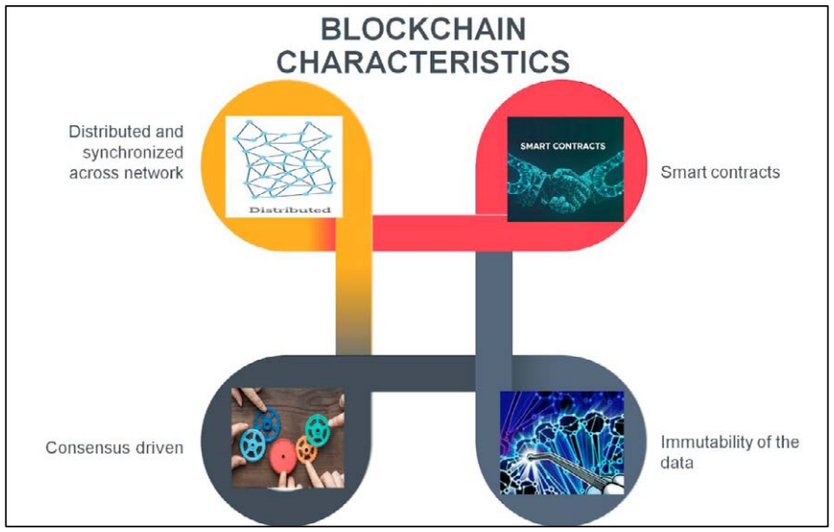

Figure 1 The Key Characteristics of Blockchain

3.1 Distributed and synchronized across networks

Blockchain is designed to be distributed and synchronized across networks which creates an ideal business network for multi-organizations. It also encourages organizations to share data.

3.2 Smart contracts

A smart contract is a software program that adds layers of information onto digital transactions being executed on a blockchain that allows for more complex transactions. In other words, it is an agreement between parties involved in a transaction that holds each party responsible for their role.

3.3 Consensus driven

Consensus is a process which needs an agreement between all relevant parties to validate any transaction before the execution of transaction. This will help to preserve erroneous or potentially fraudulent transactions out of the database.

3.4 Immutability of the data

Once a transaction is endorsed by relevant participants, it can never be changed and serves as a final record of transaction. If a user wants to change the chain, an effort is needed which is computationally hard and expensive. This secures the blockchain and establishes trust independent of a central authority which gives the idea of provenance of data.

Therefore, based on the key characteristics of the blockchain technology, these are the four main characteristics that are able to provide organizations with a high degree of trust in the data and the business network. The level of trust is very crucial for long term business applications specifically in Occupational Safety and Health Management System (OSHMS).

4.0 OCCUPATIONAL SAFETY AND HEALTH MANAGEMENT SYSTEM

Occupational Safety and Health Management System (OSHMS) is a coordinated and systematic approach to manage health and safety risk. The OSHMS consist of five main elements which are policy, organizing, planning and implementation, evaluation as well as action for improvement (ILO, 2011) as shown in Fig. 2. These elements are interrelate and interact with each other to establish and implement Occupational Safety and Health (OSH) policy and objectives for achieving organization's goals.

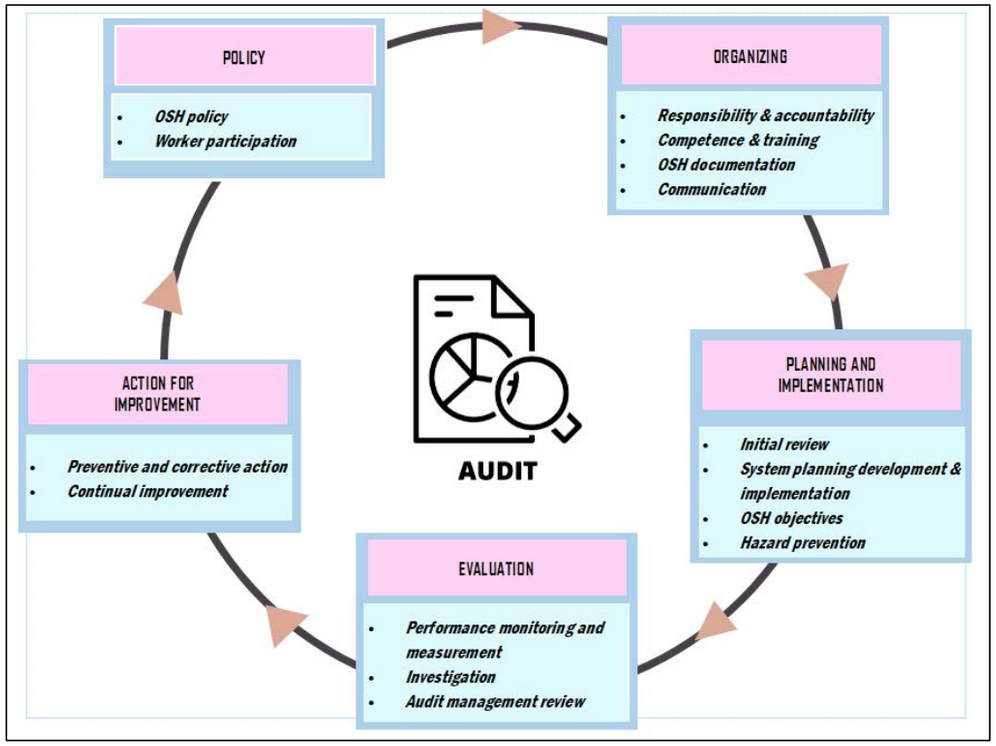

Figure 2 The OSHMS Continual Improvement Cycle (ILO, 2011)

The management systems' approach brings a number of important advantages to the implementation of OSH such as integrating and harmonizing OSH requirement, providing a logical framework for tracking action and monitoring, establishing an environment conducive in the working area and provide an auditable baseline for performance evaluation. A systems' approach also adjusts the overall safety and health programme over time which improves increasingly in decision making on hazard control and risk reduction. On the other hand, there are few limitations in the OSHMS which potentially lead to some serious problems and needs to be avoided for ensuring the effectiveness of the system.

The effectiveness of the OSHMS is depend on the size of the organization that requires to set up the system. Traditionally, organizations have documented and recorded transactions in ledgers kept under lock and key. Those ledgers are typically isolated to protect their accuracy and sanctity. Upon conducting business, each organization maintains its own separate record to independently verify information. This process has an impact on the performance of the OSHMS among organizations. By considering reliability, traceability and transparency of all data and information, a digital distributed transaction ledger is highly recommended and it should be included in the OSHMS for mitigating current organizational limitations.

5.0 THE POTENTIAL OF BLOCKCHAIN TECHNOLOGY FOR OCCUPATIONAL SAFETY AND HEALTH MANAGEMENT SYSTEM

Blockchain technology has potential to mitigate current organizational limitations in implementing an effective OSHMS. Based on the key characteristics of blockchain technology, several benefits such as reliability, data security, accuracy and cost savings can be accumulated in the OSHMS. There is one essential element that is still challenging in the OSHMS which relates to trust. Everyone trusts the old system with its inherent faults and may even be deeply vested in mitigating those faults. As a secured and trusted digital ledger, blockchain technology will store all data over democratised network and all information are secured using cryptography with identical copies maintained on multiple computer systems controlled by different blocks. Hence, any mistakes are easily verifiable. Only pertinent information is shared while the rest remains encrypted and inaccessible. As a result, immutable information makes the blockchain a tool of disintermediation. The same or greater level of trust must be demonstrated and maintained in any new system in order to be adopted and lead to commercial success. In addition, any information available in the organization will be increased and opens up the prospect for moving to lead based measures such as exposure to critical risks.

6.0 CONCLUSION

The success of Occupational Safety & Health Management System (OSHMS) is highly dependent on the reliability of the information gathered and used, where a large number of intermediaries that authenticate the information to establish trust between the stakeholders. Blockchain technology is able to execute verification by virtue of secured distributed storage. This brings about a paradigm shift in the way we establish trust and this technology is recommended to be included in the OSHMS to mitigate current organizational limitations on data management.

ACKNOWLEDGEMENTS

The work described in this paper was supported by the UTM Razak Research Fund, Universiti Teknologi Malaysia under Grant No. PY/2017/01061.

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June 2019, Vol. 16 No. 1

Original Article

HAZOP Analysis and Reliability Assessment of Closed Loop Solar Water Heater System for Residential Application

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ABSTRACT : *Solar thermal system or solar water heater system is one of the applications used to produce hot water in the residential sector. This paper describes HAZOP analysis and reliability assessment to evaluates the potential hazard and system probability for the closed loop solar thermal system applied for the residential area. Hazard identification for the main system components is analyzed while Fault Tree Analysis (FTA), Reliability Block Diagram (RBD) and Weibull distributions performed to determine the reliability for the overall system. The result shows that there are 49 potential hazards for the system with failure probability at 0.23822 and the reliability is 0.9693. Subsequently, this study determined the potential hazards for the system which can be anticipated by the residential consumer for the safety aspect. Furthermore, the evaluated reliability result shows that the application of closed loop type solar water heater system at residential premises is highly recommended due to its long lasting operational condition.*

Keywords – *HAZOP, Fault Tree Analysis, Reliability Block Diagram, Weilbull Distributions, Solar Water Heater*

1.0 INTRODUCTION

Solar thermal technology is widely applied in various sectors including residential, industry and commercial sectors for heating & cooling purposes. There are few types of solar thermal collector technology which is commercially applied depending on the temperature requirement. Solar thermal system can be divided into two types which is passive system (open loop) and active system (closed loop). For the passive system (thermosyphon and integral collector – storage system), it relies on natural convention to circulate the water and therefore the tank must be located higher than the collector panels. Meanwhile, for the active system (direct and indirect system), it utilizes pump to circulate the water between the tank and the collector (International Energy Agency, 2012). According to the literature study, it is found that a number of equipment failures for active system may occur in the solar thermal system such as the leaking of thermal storage tank, continuously develop stress in the system, collector defect, instability of the mounting structure, valve problem and pump failure. These technical issues from the equipment will possibly cause hazard towards the system and thus affecting the safety of users (Menicucci, 2009). Therefore, this paper will present the study on the HAZOP analysis and reliability assessment for the closed loop solar thermal system for water heating application at the residential area. Hazard and Operability study (HAZOP) is a qualitative method that used to identify and evaluate the initiating events (problem) that may represent risk to personnel or equipment or prevent efficient operation (Rausand, 2005). In this process, it requires to assess how big the potential risks involved where the management can focus their attention toward the most essential threats and opportunities and let the groundwork give risk response (Deloitte et al., 2012). Reliability is a useful method used to identify and quantify equipment and system failures that will prevent the achievement of its objectives. It consists of several tools such as fault tree analysis and lifetime data analysis by using Weibull distribution (International Energy Agency Solar Heating and Cooling Programme, 2015). However, it is

difficult to estimate the reliability parameters of the systems up to a desired degree of accuracy by utilizing available information and uncertain data (Komal et al., 2010). Fig. 1 shows the process flow diagram for the simulation design system of solar water heater to be studied.

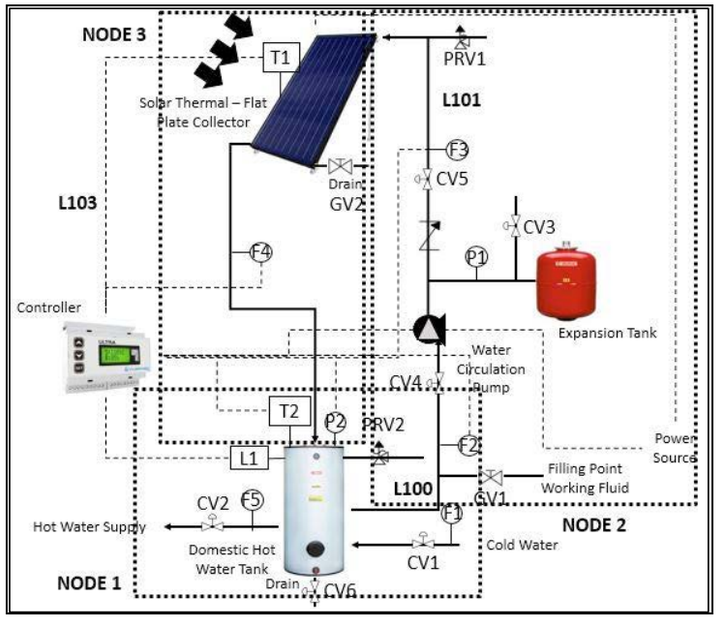

Figure 1 Schematic Diagram for Closed Loop Solar Water Heater System at Residential Area

This system is independent from the electrical water heater to provide the heating requirement during night time as it is supported with big storage tank. The cold water is fed into the storage tank with control valve (CV1) and flow sensor (F1) functioning to monitor the flow rate of cold water into the storage tank. The working fluid function as a heat transfer fluid and it is a mixing between water and glycol in a liquid phase only based on the ASHRAE Standard (American Society of Heating, Refrigerating and Air-Conditioning Engineers, 1991). This heat transfer fluid flows through the heat exchanger coil inside the storage water tank in closed loop pipeline system to transfer the thermal heat into the cold water inside the tank and then continuously flow through the solar collector drive by the circulating pump to absorb the energy from sun during bright day. The flow rate of working fluid is controlled by flow sensor (F2) and control valve (CV4) as it passes through pump and managed by control valve (CV5) and flow sensor (F3) after the pump system as it flows into the solar collector.

The gate valve (GV1) is used as an entry point to inject the working fluid if the volume is insufficient in the pipeline. It will ensure the volume of fluid is adequate to help in run the system by transferring the thermal energy. During the day time, the flat plate solar collector, which is mounted on top of the house roof, is exposed to sunlight and it will absorb the energy on the surface of essentially planar according to the working principle in ASHRAE standard. It will get hot, thus transferring the sun energy to the working fluid in a heat form (American Society of Heating, Refrigerating and Air-Conditioning Engineers, 1991). The working fluid temperature is monitored by using temperature sensor (T1) which is installed on the solar collector while the flow rate is controlled by the flow sensor (F4) at line L103. The cold working fluid will be pumped back to the solar collectors for reheating process and non – return valve (NRV) is installed to ensure the fluid will only flow in one direction. The hot water is stored inside the same storage tank and its temperature is measured by temperature sensor (T2).

When there is a demand for hot water from users, it control valve (CV2) and flow sensor (F5) will ensure the flow rate demand is met. The level sensor (L1) and pressure sensor (P2) will the water level and pressure inside the storage tank will not exceed the allowable limit. If there is a sign of overflow in the storage tank, it will be detected by control valve (CV6) and if the pressure exceeds the set value, the pressure relief valve (PRV2) will respond accordingly. A controller system will manage the overall system and ensure that the fluid will circulate to the collector when there is sufficient heat available and supply the hot water to the producer at the stipulated temperature. For the piping system, the pressure will be monitored by the pressure sensor (P1) and when the pressure is too high, the pressure relief valve (PRV1) will act to reduce the high pressure build up.

2.0 METHOD

Hazard and Operability Study (HAZOP) method is used to identify process hazards and potential operating problems by using a series of guide words to study process deviations. Reliability analysis involves fault tree analysis and lifetime data analysis by using Weibull distribution for reliability part. Each of the main components involved are identified including solar collector, pump station (circulating pump) and solar controller, expansion tank and storage tank with heat exchanger. There are 3 nodes for HAZOP analysis as shown in Fig. 1. The data of the failure rate will be collected from available resource and reference. Fig. 2 shows the steps in constructing the HAZOP study and Fig. 3 shows the overall step to construct the reliability study. Weibull distribution is a mathematical method applied to estimate the life characteristic of the components in the system in terms of failure rates and reliability.

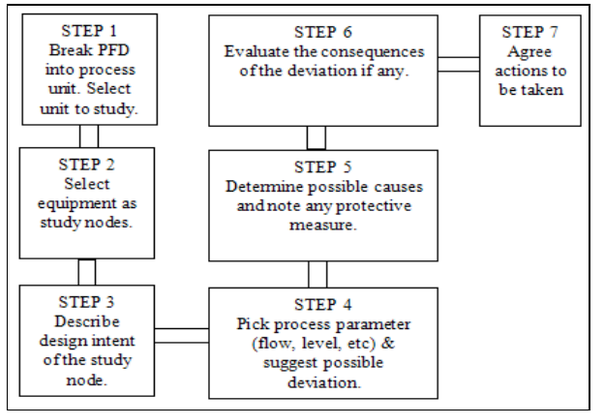

Figure 2 Steps in Constructing HAZOP Analysis

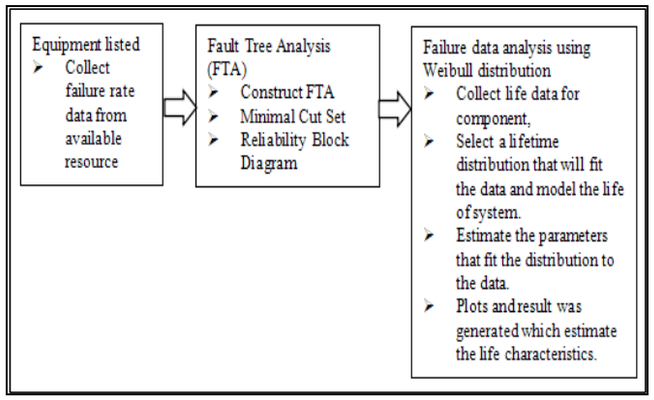

Figure 3 Step in Constructing Reliability Assessment

Table 1 Probability and Frequency of Each Gate and Formula Used in Weibull Distribution

Parameter	Input pairing	Formula	Equation
OR gate	P_A OR P_B	P (A OR B) = 1 – (1-P_A)(1-P_B)	(1)
AND gate	P_A AND P_B	P (A AND B) = P_AP_B	(2)
Probability density function (pdf)		$f(t) = \frac{\beta}{\alpha}\left(\frac{t}{\alpha}\right)^{\beta-1} e^{-\left(\frac{t}{\alpha}\right)^{\beta}}$	(3)
Cumulative distribution function (cdf)		$F(t) = 1 - e^{-\left(\frac{t}{\alpha}\right)^{\beta}}$	(4)
Reliability (Survival function)		$R(t) = e^{-\left(\frac{t}{\alpha}\right)^{\beta}}$	(5)

3.0 RESULTS

3.1 Hazard and Operability Study (HAZOP) Analysis

For HAZOP analysis, findings were recorded and presented in Table 2, Table 3 and Table 4. Table 2 shows Node 1, which focuses on the inlet of cold water supply via CV1 and F1 to domestic hot water tank (DHWT) and the hot water supply outlet.

Table 2 Identification of Causes and Recommendations for Node 1

Item	Deviations	Possible Causes	Recommendation
Domestic Hot Water Tank (DWHT)	More Flow	Flow indicator (F1) and level indicator (L1) malfunction	1) Install Level Alarm High (LAH) at DHWT
		Control Valve (CV1 & CV2) malfunction due to incorrect input signal	2) Safety Operating Procedure
	Less Flow	Control Valve (CV1) partially open	1) Safety Operating Procedure
		Leakage at cold water supply	2) Periodic Maintenance
	No Flow	Control valve inadvertently closed / flow indicator fail open	Safety Operating Procedure
		Blockage cold water line	
	High Pressure	Pressure relief valve (PRV2) inadvertently closed	
	Low Pressure	Drop performance of DHWT	
	High Temperature	Temperature indicator (T2) malfunction	Install Temperature Alarm High (TAH)
	High Level	Flow indicator and level indicator (L1) malfunction	Install Level Alarm High (LAH) at DHWT
	Low Level	Control valve partially closed	Install Level Alarm Low (LAL) at DHWT
		Flow indicator partially open (wrong set point) / Control valve inadvertently partially closed	
	Other than Concentration	Presence of debris accumulation	Install Filter/Strainer before entering DHWT

Table 3 refers to Node 2 which covers from the working fluid flow to collector via water circulating pump. In this node, it was divided into two items which are feed line L100 and line L101 to flat plate collector and circulating pump.

Table 3 Identification of Causes and Recommendations for Node 2

Item	Deviations	Possible Causes	Recommendation
Feed Line to Flat Plate Collector	Less Flow	Leakage/ Insufficient cooling water supply	1)Safety Operating Procedure
			2)Periodic Maintenance
	No Flow	Blockage cold water line	1) Safety Operating Procedure
		Control valve fails to close or blocks	2) Install temperature indicator and controller to control tracing
			3) Regular inspection and maintenance of control valves
	Reverse Flow	Pump fail	
	High Pressure	Pump over speed/ overpressure	Install Pressure Indicator and Pressure Alarm High (PAH)
	Low Pressure	Pump poor performance	Install Pressure Alarm Low (PAL) and periodic maintenance
	High Temperature	Cold water system fails	Install Temperature Indicator and Temperature Alarm High (TAH)
	Other than Concentration	Presence of debris accumulation	
Circulating Pump	More Flow	Flow indicator (F3) fails, opening control valve (CV5)	
		Control valve fails open	
	Less Flow	DHWT storage empty	Install Level Alarm at DHWT
		Line 100 plugs	Use manual valve system
		Line 101 plugs	
		Check valve (NRV) fails closed	
	No Flow	No level inside stock tank	
	Irregular Flow	Fluctuated pump performance	Restricted Orifice (RO)
	High Pressure	Control valve (CV5) fails closed	Use manual valve system
		Check valve (NRV) fails closed	Use manual valve system
		Line 101 plugs	
		Flow indicator (F3) fails, closing control valve (CV5)	
	Low Pressure	Control valve (CV5) fails open	Use manual valve system
		Line 100 plugs	Periodic maintenance
		DHWT storage empty	Install Level Alarm at DHWT
		Flow indicator (F3) fails, opening control valve (CV5)	Use manual valve system
	High Temperature	Control valve (CV5) fails closed	
		Check valve (NRV) fails closed	
		Line 101 plugs	
		Flow indicator (F3) fails, closing (CV5)	

Fig. 1

For the last node refer to Table 4, it is focusing on hot working fluid line from flat plate collector, flow to domestic hot water tank (DHWT). Only one item recorded which is in line L103 to domestic hot water tank (DHWT).

Table 4 Identification of Causes and Recommendations for Node 3

Item	Deviations	Possible Causes	Recommendation
Line L103 to Domestic Hot Water Tank (DHWT)	More Flow	Flow Indicator (F4) malfunction due to incorrect input signal	
	Less Flow	Flow Indicator (F4) malfunction due to incorrect input signal	Install flow control valve
	No Flow	Flow Indicator (F4) malfunction - Fail open	Safety operating procedure
	High Pressure	High pressure hot water supply	Troubleshoot flat plate collector
	Low Pressure	Low pressure hot water supply	Troubleshoot temperature indicator
		Leakage at hot water L103 supply	
	High Temperature	High temperature hot water supply	
	Low Temperature	Temperature Indicator (T2) malfunction due to incorrect input signal	Install temperature control valve

3.2 Reliability Assessment

The data on the failure rate was collected from several sources and each symbol is listed in Table 5 below. Failure rate is required in order to calculate the reliability of each parameter. The reliability of each parameter has been calculated by using the formula indicated in this table and with the purpose of finding the value of failure probability.

Table 5 Failure Rate Data from Several Sources

Parameter	Symbol	Failure rate, λ (per year)	Refs	Reliability $R = e^{-\lambda t}$	Failure probability, P = 1-R
Leak Tank	B1	0.150672	IAEA [8]	8.6013E-01	1.3987E-01
Control Valve Fail	B2	0.15	FCEE UTM [8]	8.6071E-01	1.3929E-01
Pipe Corrode	B3	0.0001	UK HSE [10]	9.9990E-01	9.9995E-05
Pump Fail to Run	B4	0.297840	US DOE [11]	7.4242E-01	2.5758E-01
Pressure Relief Valve Fail	B5	0.002	FCEE UTM [9]	9.9800E-01	1.9980E-03
Pump Fail to Stop	B6	0.12264	US DOE [11]	8.8458E-01	1.1542E-01
Temperature Sensor Fail	B7	0.027	FCEE UTM [9]	9.7336E-01	2.6639E-02
Controller Fail	B8	0.149796	IAEA [8]	8.6088E-01	1.3912E-01
Collector Fail	B9	0.099864	US DOE [11]	9.0496E-01	9.5040E-02
Pump Breakdown	B10	0.021462	OREDA [12]	9.7877E-01	2.1233E-02
Power Tripped	B11	0.0122640	US DOE [11]	9.8781E-01	1.2189E-02
Expansion Tank Fail	B12	0.134028	IAEA [8]	8.7457E-01	1.2543E-01
Gasket Fail	B13	0.000005	UK HSE [10]	1.0000E+00	5.0000E-06
Pump Leakage(Internal)	B14	0.0069204	OREDA [12]	9.9310E-01	6.8965E-03
Casing Fail	B15	0.00003	UK HSE [10]	9.9997E-01	3.0000E-05
Pump Seal Fail	B16	0.007008	FCEE UTM [9]	9.9302E-01	6.9835E-03
HEX in Storage Tank Fail	B17	0.28908	IAEA [8]	7.4895E-01	2.5105E-01

The fault tree diagram is generated based on the failure parameter in Table 5 (Fig. 4). The advantage of this approach is the inclusion of their impacts on each other. Table 6 shows the results of probability, P for each gate in the FTA.

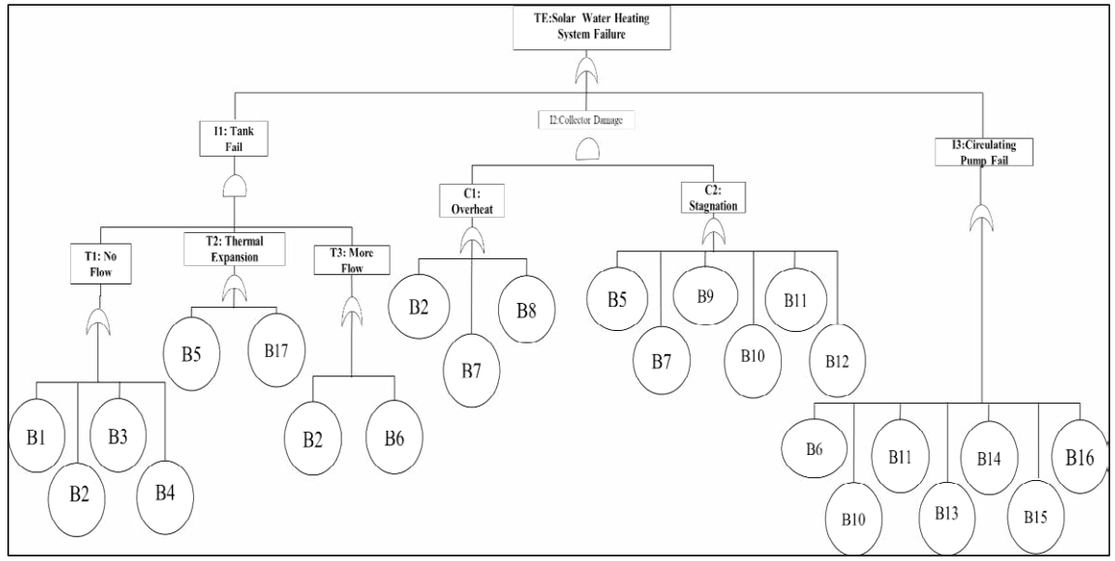

Figure 4 Fault Tree Analysis of Solar Water Heating System

Table 6 Probability of Each Gate

Input pairing	Probability, P
P_{T1} (B1 OR B2 OR B3 OR B4)	4.5043E-01
P_{T2} (B8 OR B17)	2.5254E-01
P_{T3} (B2 OR B6)	2.3863E-01
P_{C1} (B7 OR B2 OR B8)	2.7145E-02
P_{C2} (B7 OR B9 OR B10 OR B11 OR B12 OR B5)	2.7877E-01
P_{I1} (P_{T1} AND P_{T2} AND P_{T3})	2.5667E-01
P_{I2} (P_{C1} AND P_{C2}))	7.1552E-02
P_{I3} (B10 OR B11 OR B13 OR B14 OR B15 OR B16 OR B6)	1.5661E-01
P_{SYSTEM} (P_{I1} OR P_{I2} OR P_{I3})	2.3822E-01

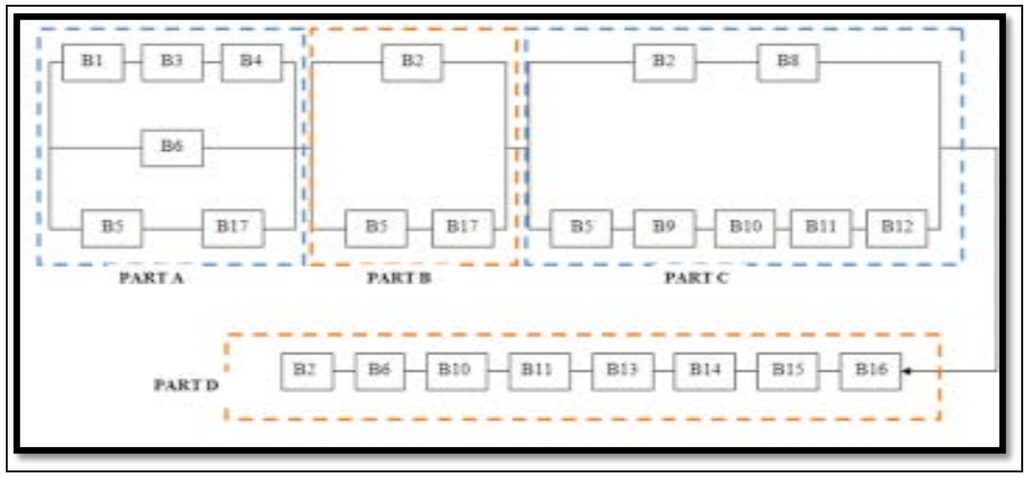

Figure 5 Reliability Block Diagram of Solar Water Heater System

From the minimal cut set by using mathematical form of Boolean algebra, system reliability and analysis can be transformed into the block diagram to illustrate the network relationships as shown in Fig. 5. For Fig. 6, 7 and 8, they show the graph by using Weibull distribution (two parameters) of which α indicates scale and β is shape parameter. From the FTA diagram, storage tank, solar thermal collector and circulating pump are defined as intermediate events. Therefore, the scale and shape for each of the solar water heater system components will be derived from probability plotting serial of data that will be computed in the excel tool. The shape value for storage tank, collector and pump are 3, 2.5 and 2.09 respectively while for scale value they are 7.5, 6.5 and 6.6 respectively. All graphs in Fig. 6, 7 and 8 plotted based on failure data collected and by using equation (3), (4) and (5) respectively. From equation (4), the cumulative distribution function data is plotted in graph.

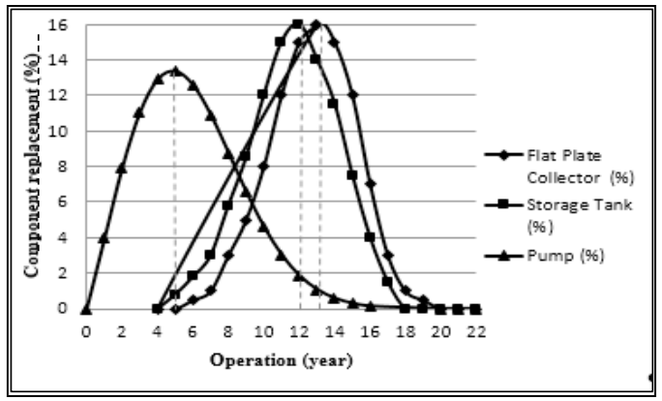

Figure 6 Component Replacement in SWH System

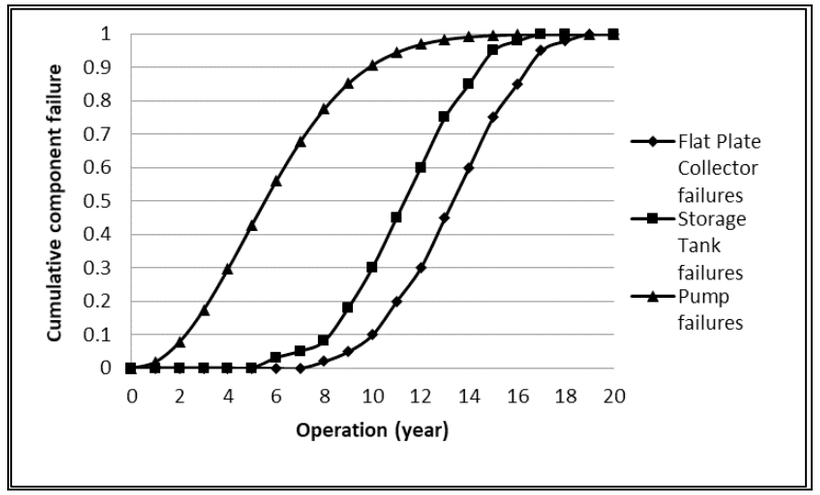

Figure 7 Cumulative distribution function

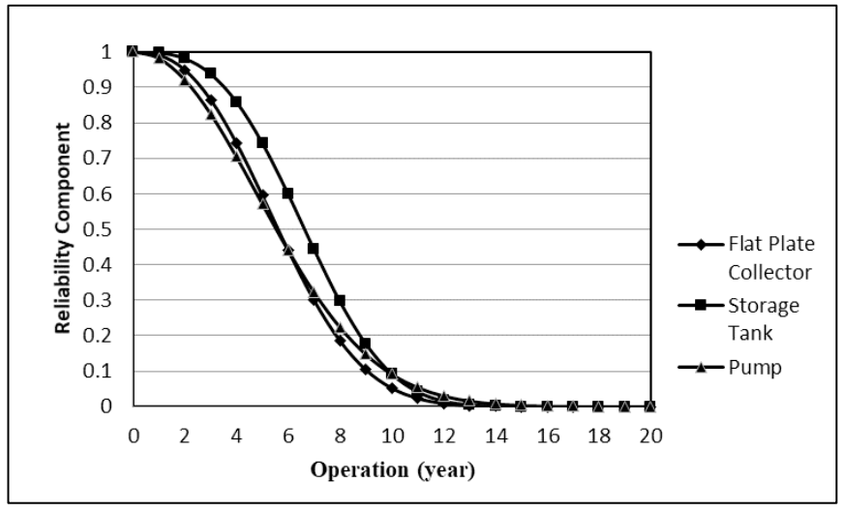

Figure 8 Reliability (Survival Function) of SWH System

4.0 DISCUSSION

The suitable parameter chooses that related to node 1 consists of flow, pressure, temperature, level and concentration with suitable deviation based on Table 2. There are five actions that need to be taken to address the HAZOP parameter of flow which may have three different deviations (more, less and no). While for the level parameter in, two actions need to be taken which are installing level alarm high and level alarm low at DHWT. Only one action required (install temperature alarm high at DHWT) for the temperature parameter. For Table 3, the parameters involved including flow, pressure, temperature and concentration for first item. While for the second item, only flow, pressure and temperature were involved. For first item, there are five actions highlighted to be taken for flow parameter, two actions (install pressure indicator and pressure alarm high and install pressure alarm low and periodic maintenance) suggested for pressure and only one action recommend (install temperature indicator and temperature alarm high) for temperature. For the second item, parameter flow has three actions being suggested, while there are six actions need to be taken for pressure where some actions are repeated for different causes. In Table 4, flow, pressure and temperature were involved as parameters. There are two actions recommended for flow and pressure parameters respectively while only one action (install temperature control valve) suggested for temperature parameter.

The step to construct FTA as shown in Fig. 4 is based on top event connected to intermediate event, sub intermediate event and basic event. Firstly, the storage tank requires three sub intermediate events to occur (no flow, thermal expansion and more flow) in order for the storage tank to fail. Secondly, overheating and stagnation of intermediate events must occur to contribute to collector damage. Lastly, the circulating pump will fail when any of the 7 of basic events occurs. The storage tank can fail if no cold-water was supplied into the tank and no heat transfer from the working fluid. The thermal expansion can occur and cause explosion if the tank temperature is high. If more water flows into the tank, it will overflow and contribute to tank fail. If the temperature is too high, overheating can occur and could cause collector damage. Stagnation occurs if flow of working fluid is interrupted, causing the solar collector to absorb more heat that cause damage to collector. Therefore, 24 basic events identified for three intermediate events including collector, tank and pump and which there are seven similar basic events repeat such as control valve fail (B2), pressure relief valve fail (B5), pump fail to stop (B6), temperature sensor fail (B7), pump breakdown (B10) and power tripped (B11) for different intermediate event.

The overall probability for solar water heating system is 0.23822 by referring to Table 6. It indicates that the probability of the system to fail is very low by using equation (1) and (2) in Table 1. The computational process is based on Boolean algebra mathematical rule for minimal cut set. From Fig.5, the solar water heater system is a combination of series and parallel configuration. The RBD has been divided to four parts for better explanation. It begins with part A with series configuration of three basic events which are B1, B3 and B4 that are connected parallel to B6 and parallel to the series arrangement of B17 and B5. For part B, the basic event B2 is parallel to the series configuration of B5 and B17. Part C shows the series configuration of B2 and B8 basic event is connected parallel to series arrangement of B5, B9, B10, B11 and B12. Finally, for part D, it only has the combination of 8 basic events that in series configuration which are B2, B6, B10, B11, B13, B14, B15 and B16. The connection for part A, B C and D are series configuration. Subsequently, in series configuration, if any basic event fails to operate, it will result in the failure of the entire system. For example, if any of the eight basic events of part D fails, the solar water heater system will not function. In other words, all of eight basic events must succeed and operate in good condition to ensure that the solar water heater system could succeed in producing the hot water. Parallel arrangement is also called as redundant unit. At least, one of the units (basic event) must function for the system to operate. As presented in part B, at least B2 or unit (B5 and B17) must be functioning for the solar water heater system to operate.

Fig. 6 shows the probability of component replacement due to failure, in which the pump has the highest failure in the first year compared to other components. From the graph, the mode value (the highest failure rate) for the flat plate collector, storage tank and pump are 13 years, 12 years and 5 years respectively. The highest failure rate of collector and storage tank was 16% while pump failure rate is around 13.37 %. The failure frequency of pump is the highest compared to other components. The figure shows that the pump requires maintenance 5 years of operation. The number of failure decreases after 5 years since the sequence maintenance and replacement certain parts of pump. While for collector the graph declines after 13 years of operation because reduction in number of remaining collector still intact. Fig. 7 illustrates cumulative distribution function of component in solar water heater (SWH) system. According to the graph 10% of collector will face some sort of part component failures within 10 years, which is less compared to storage tank (30%) and pump (90%). In 10 years, the pump requires regular replacement of parts and service.

Fig. 8 shows the reliability of three components in solar water heater system where the probability of each component will be operating over some period of time. The survival of all three components reduces the times rises. The reliability plotted only models the time until the failure occurs without concern for the time to repair. The estimation of reliability of each component in one year for storage tank, flat plate solar thermal collector and circulating pump are 0.9976, 0.9907and 0.9808 respectively. It indicates that the pump has the highest frequency for its components to fail completely compare to other two SWH components due to expected wear and tear. Other factors include the circulating pump is operating at high temperature above the operating temperature as the solar collector is absorbing more heat from the sun during hot days due to the fluctuation of the climate condition. The reliability graph for flat plate collector component become zero after 12 years of operation. After

13 years, the survival of storage tank and circulating pump become zero and for is after 12 years. Therefore, the storage tank and circulating pump have better life time even though slightly different in terms of reliability.

5.0 CONCLUSION

The HAZOP analysis has identified several causes for each of the three nodes of the solar thermal heating system which can potentially lead towards the system failure. There are few actions being highlighted to address all 49 potential hazards and to enhance the safety level of the system for the safety users. The FTA has determined 24 basic events for three intermediate events including collector, tank and pump and there are 7 similar basic events repeat such as B2, B5, B6, B7, B10 and B11. The calculated failure probability of the system is 0.23822. Weibull probability distribution identified the probability density function for three components and it is found all the components increase exponentially against time. The estimation reliability of each component in 1 year for storage tank is 0.9976, collector (flat plate) is 0.9907 and circulating pump is 0.9808. The computed reliability for the overall system is 0.9693 which indicates that this independent closed loop solar water heater system is long lasting.

ACKNOWLEDGEMENT

The authors would like to acknowledge the Ministry of Education of Malaysia and Universiti Putra Malaysia for the support given to this study. Special gratitude to the industry players and subject matter experts for sharing the knowledge on this solar thermal technology for water heater application at residential premises.

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Original Article

Impulsivity, Online Disinhibition, And Risk Taking Among Digital Millennials: Challenges of e-Safety in Industry 4.0

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ABSTRACT : *Digital Millennials (i.e., people born from 1980 to 2004) have often been portrayed as quick to embrace emerging technologies. The envisioned future of Industry 4.0 entails the blending of hardware, software, and people to complete work; and given their affinity for digital resources, technology, and social networking applications, the Millennials could be regarded as a much-needed asset in this future workforce. However, systematic research on how this cohort understands and reacts to safety issues surrounding the use of technologies has been lacking. In particular, behaviours such as impulsivity, online disinhibition, and risk-taking among them remain unclear. The present study investigated this gap with a sample of 203 Millennials of various nationality groups. Using the short version of the Urgency, Premeditation, Perseverance, Sensation Seeking, and Positive Urgency (Short UPPS-P) scale, the Revised Online Disinhibition Scale, and the Online Risky Behaviour scale, the results indicated that the most significant predictors of online risk-taking behaviours are lack of premeditation, positive urgency, and toxic disinhibition. Interestingly, though not hypothesised, was gender as a significant predictor of the outcome. The findings implied that these variables might be the most relevant target areas for interventions that could modify risky behaviours in cyberspace. The study's findings are discussed in relation to the key challenges associated with e-safety where the future trends would be heading towards the gig economy and crowd-working.*

Keywords – *e-Safety, Impulsivity, Industry 4.0, Millennials, Online Disinhibition, Risk-taking.*

1.0 INTRODUCTION

New developments in data volume, analytics, and mobility have accelerated the Fourth Industrial Revolution or Industry 4.0 and contribute to the formation of new entrepreneurs, start-ups, innovations, and different forms of work. In this Industry where people and machines (both hardware and software) interact as cyber-physical systems (Baldassari & Roux, 2017), the workplace is no longer defined by its physical space nor is it limited to the normal office hours. In fact, the nature of work in Industry 4.0 has considerably changed and is now characterised by the use of online platforms and wireless mobile technologies for work-related tasks (Greis et al., 2012), accessibility of organisation's data via cloud network facilities (Baldassari & Roux, 2017), short-term engagements among employers, workers, and customers (Kalleberg & Dunn, (2016), and a greater emphasis on collaboration as the primary mode of work and play (Greis et al., 2012). These aspects, however, present significant challenges for organisations as they can expose businesses to e-safety threats.

The use of the Internet has become very integral in many companies and organisations as more and more workers are using computers, gadgets, devices, and applications as part of their job. This increased use has concurrently led to concerns about e-safety in the workplace. In general, e-safety refers to the safe practice and responsible use of information communication technology and all electronic devices – this may include the way people are taught about risks online, how they can protect themselves, and to whom they should report worrying activities (Barnard-Wills, 2012, p. 240). While the majority of e-safety concerns have focussed on children or young people, reports and anecdotes have increasingly shown that

issues such as data privacy, security, ownership, governance, and regulatory compliance are also the key concerns for organisations. Nevertheless, many workers may not be aware of these issues; hence, thrusting them into committing risky behaviours, which, in turn, can create vulnerabilities in the organisation's cyber environment. Therefore, knowing how to address these issues has become essential to achieve the maximum benefit from the new and developing technologies without putting the organisations and workers at undue risk. Embedded in every organisation is the "duty to care" (Heads Up, 2019), and this requires organisations to take steps to ensure that an appropriate culture of safety and responsibility is instilled and practised by the entire workforce.

Research on risky behaviours are extensive in the literature - from analysing the process of decision making (Reyna & Farley, 2006) to the attempts at quantifying risky behaviour tendencies for clinical purposes (Reid et al., 2014). However, only a few studies have focused on online behaviours among young adults or the *Digital Millennials*. Risky behaviours can be defined as any actions with potentially undesirable outcomes (Boyer, 2006), and if we extend this definition to online settings, it can be said that many online behaviours can be considered as risky. Lau and Yuen (2013) further conceptualised online risk-taking behaviours or risky behaviours as having three domains, i.e., (1) unauthorised acts such as using pirated softwares or unauthorised passwords, (2) internet stickiness, which refers to the feeling of the need to constantly be connected online, and (3) online plagiarism, for example, submitting assignments with contents or pictures copied from the Internet without acknowledgements, copying assignments, or pasting others' articles in the discussion forum on the Internet without permissions, among others.

Studies have shown that risk-taking behaviours are associated with impulsivity, i.e., the tendency to act in rapid or unplanned reactions towards internal or external stimuli with diminished regard to consequences (Reynolds et al., 2006). Cyders and Smith (2008) argued that impulsivity is not composed of one construct but is subdivided into five domains. These domains are: (1) negative urgency, i.e., the tendency to make rash decisions under negative emotion, (2) lack of perseverance, i.e., the inability to persist on a task that may be boring or difficult, (3) lack of premeditation, i.e., the tendency to act without consideration of potential consequences, (4) sensation seeking, i.e., tendency to seek excitement and adventure, and (5) positive urgency, i.e., the tendency to act rashly in response to positive affect (Cyders et al., 2007; Whiteside & Lynam, 2001).

Another variable of growing interest in current risk-taking behaviour research is that of *online disinhibition effect* (Suler, 2004) – a phenomenon whereby individuals become socially uninhibited when communicating in online environments or digital mediums. Suler (2004) suggests that online disinhibition involves the dissipation of personal restraints, which may cause unrestricted expressions such as discourteous acts, rude or harsh language, aggressive behaviours, as well as anger, hatred, and threats in online settings. In this form, the online disinhibition is known as toxic disinhibition (Suler, 2004). On the other hand, online disinhibition may also be positive. For example, people may reveal or share personal things like their emotions, fears, and wishes or show a strong will to help others or display unusual acts of kindness or generosity. This is known as benign disinhibition (Suler, 2004).

Millennials are projected to make up 50% of the workforce by 2020, and the U.S. Bureau of Labour Statistics predicts that this generation will become the largest segment of the labour force with participation rate at 75% by 2030 (Mitchell, 2013). There are some variations in how different people define Millennials. The most commonly used definition, however, is by Howe and Strauss (2003) who describe this generation as a general cohort of those born between 1980 and 2004. Although considered to be well-versed in technology and are digitally driven, Millennials are known to be at risk from threats in cyberspace such as online harassment and cyberbullying, exposure to problematic contents, sexual solicitation, identity threats, and internet addiction (Schrock & Boyd, 2008; Whitaker & Bushman, 2009).

Studies such as those by Baumgartner, Valkenburg, and Peter (2010), and White et al. (2018) have shown that the number of Millennials engaging in various types of risky behaviours in online settings and cyberspace is increasing, and the vast majority of these behaviours involved cyberbullying, risky information sharing, sexual soliciting, and risky self-presentation. Because Millennials will make up the largest generation in the workforce, their risky online behaviours are particular concerns of organisations. Their attitudes toward freedom of information, prizing innovation over security and stability, increasing trust in technology, and feelings of security in the virtual world may expose employees and organisations to cyber vulnerabilities, especially those who do not have the adequate resources to protect themselves against unsafe technology use by the Millennial workers (Greis et al., 2012).

Although Industry 4.0 and Industrial Internet of Things (IIoT) offers opportunities for innovation, entrepreneurship, flexibility, and autonomy, they also provide an ideal environment for risk-taking, and workers may be tempted to engage in risky behaviours. This is more so for the Millennials as they are reported to have a lack of awareness of organisational cybersecurity policies (Accenture, 2010) and routinely bypassed their organisation's approvals and policies when using various devices, technologies, and social networking websites at work (Myers & Sadaghiani, 2010). In short, extensive access and indiscriminate use of the internet and technologies by workers can expose businesses to new and higher risks and liabilities, which compels us to investigate further their attitudes and digital behaviours. However, to date, there exist only a few studies on online risk-taking behaviours among adults, especially the Millennials. Nevertheless, evidence in the wider literature in offline settings has suggested that impulsivity (Cyders & Smith, 2008; Ginley et al., 2014) and disinhibiting behaviours (Suler, 2004; Udris, 2016) are positively associated with the tendency to engage in risky behaviours. As such, the present study

explored the relationships between impulsivity, online disinhibiting behaviours, and online risk-taking behaviours among the Millennials. Following the conceptualisation of impulsivity by Cyders et al. (2014), five domains, namely urgency, premeditation, perseverance, sensation seeking, and positive urgency, were examined together with two online disinhibition domains, i.e., benign and toxic disinhibition (Udris, 2016). These variables are then hypothesised to predict online risk-taking behaviours, which consisted of unauthorised acts, internet stickiness, and plagiarism (Lau & Yuen, 2013), as illustrated in Fig. 1.

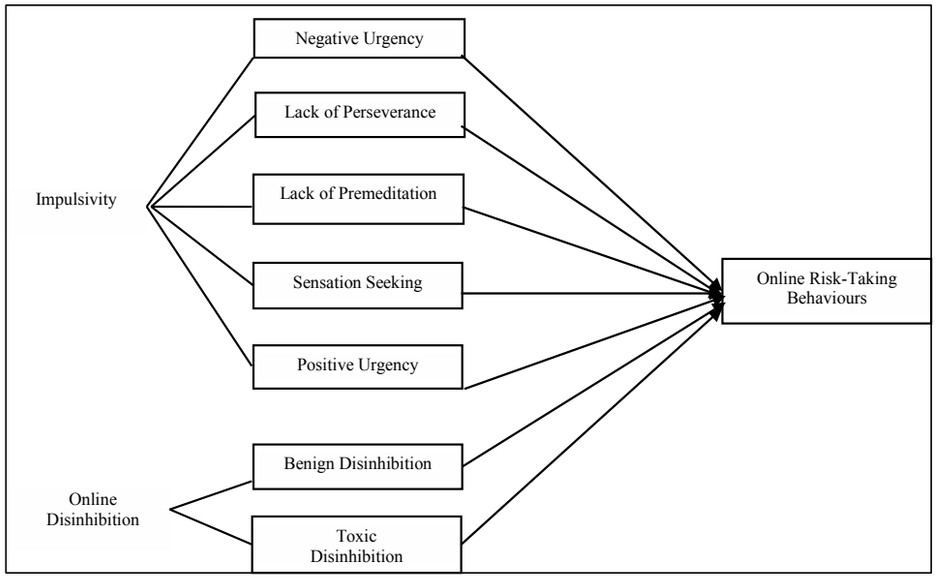

Figure 1 Conceptual Framework of the Study

2.0 METHOD

2.1 Study Design and Participants

This study used a cross-sectional design in which 203 participants according to the inclusion criteria (i.e., Millennials born from 1980 to 2004) responded to a self-report questionnaire. The mean age of participants was 21.15 years, with age ranged between 19 to 25 years old. The majority of them are Malaysians (44.8%), followed by Indonesians (35%), and other nationalities (20.2%). However, more females (64.5%) responded to the questionnaire compared to males (35.5%).

2.2 Materials and Measures

Data were collected through a questionnaire that consisted of two sections. The first section included participants' demographic information, while the second section contained three scales related to impulsivity, online disinhibition, and online risk-taking behaviours. Impulsivity was measured by the short version of the Urgency, Premeditation, Perseverance, Sensation Seeking, and Positive Urgency (Short UPPS-P) scale by Cyders et al. (2014). This scale, which is rated on a four-point Likert scale ranging from 1 (*Agree Strongly*) to 4 (*Disagree Strongly*), has 20 items with four items in each domain, namely negative urgency, lack of perseverance, lack of premeditation, sensation seeking, and positive urgency. Total subscale scores were used for data analyses, with higher scores indicating a higher presence of the respective impulsive behaviour. Adequate internal consistencies were obtained for all subscales, i.e., negative urgency (Cronbach's α = .53), lack of perseverance (Cronbach's α = .61), lack of premeditation (Cronbach's α = .75), sensation seeking (Cronbach's α = .75), and positive urgency (Cronbach's α = .78).

Online disinhibition was measured using the Revised Online Disinhibition Scale (Udris, 2016). This scale consisted of 11 items, with seven items measuring benign disinhibition and four items measuring toxic disinhibition. The response scale is based on a four-point Likert scale, ranging from 0 (*Disagree*) to 3 (*Agree*), with higher scores representing higher

disinhibiting behaviour. Reliability of both subscales was good with Cronbach's alphas of .78 for benign disinhibition and .73 for toxic disinhibition. Finally, online risk-taking behaviours were measured using the Online Risky Behaviour Scale (Lau & Yuen, 2013). This scale is a 10-item self-report measure consisted of three subscales, namely unauthorised activities, internet stickiness, and plagiarism. All items were scored on a five-point Likert-type response scale, ranging from 1 (*Strongly Disagree*) to 5 (*Strongly Agree*). Both the total score and subscale scores can be computed. However, only the total scores for online risk-taking behaviours are reported in this study. A higher total score indicates a higher tendency that an individual may engage in online risky behaviours. In this study, the Cronbach alpha for this scale was .812. The questionnaire was administered in English because the participants were Millennials who had a minimum of a secondary school degree and thus are expected to have an adequate understanding of the language.

2.3 Procedures

Ethics approval was obtained from the Research, Publication, and Innovation Ethics Committee of the Department of Psychology, International Islamic University Malaysia before data collection began. Prior to the commencement of the study too, the authors of the three scales were contacted, and permissions were granted to use the scales in this study. The data collection involved two phases. In the first phase, a pilot study was conducted to improve the questionnaire and to refine the data collection process. Participants in this phase (n = 6) indicated that the questionnaire was understandable and that only minor layout changes were required. The questionnaire was then revised accordingly. To increase the response rate, the main data collection was carried out using both paper and online survey forms. A written description of the study was provided in both forms, and all participants gave their consent to participate in this study. The data collection process lasted for two weeks, and at the end of the study, a lucky draw was held. The selected participants received a token as an appreciation for their participation in this study.

3.0 RESULTS

All analyses were conducted using IBM SPSS version 23.0. Data were checked for the assumptions underlying multiple regression before performing the analyses, and the results showed that with n = 203 in this study, the recommended sample size of 106 calculated using Tabachnick and Fidell's (2014) formula of $n > 50 + 8m$ (where m = number of predictors) was met. In addition, the residuals are normally distributed, the variances of the residual terms were homoscedastic, and the residuals at each level of predictors have similar variance after inspecting the normal probability plots and residuals scatterplots. No variance inflation factor (VIF) values larger than 10, and no Tolerance values lower than 0.1 as recommended in Field (2013) are detected - indicating that multicollinearity was not a concern. Finally, the assumption of independent errors was met wherein the Durbin-Watson values for all predictors are close to 2, as recommended by Field (2013). Altogether, these results showed that the data were appropriate for conducting multiple regression analyses.

First, descriptive statistics were computed for all variables of interest and the results are presented in TABLE 1. With an n = 203, there were no missing data on any variable except positive urgency where four male participants did not answer all questions in this scale. These missing data were only about 2% of the whole sample, which is very small, and thus, did not affect the analyses and findings of this study. Next, two hierarchical multiple regressions were conducted to test impulsivity and online disinhibition as predictors of online risk-taking behaviours following the framework depicted in Fig.1.

Table 1 Descriptive statistics of all variables

No.	n	Predictors														Outcome	
		Negative Urgency		Lack of Perseverance		Lack of Pre-meditation		Sensation Seeking		Positive Urgency[§]		Benign Disinhibition		Toxic Disinhibition		Online Risk-Taking Behaviours	
		M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Male	72	10.14	2.16	7.18	1.88	7.61	1.98	12.07	2.71	9.59	2.94	11.67	4.74	3.28	3.08	25.89	6.97
Female	131	9.93	1.87	7.26	1.77	7.86	1.93	11.56	2.35	9.31	2.41	11.50	4.30	1.86	2.23	22.51	6.36
Total	203	10.01	1.98	7.23	1.81	7.77	1.95	11.74	2.49	9.40	2.60	11.56	4.45	2.37	2.65	23.71	6.77

[§]Note: For Positive Urgency: Male = 68, Female = 131. This missing data were less than 5% and were handled through listwise deletion.

In the first hierarchical multiple regression, we examined which impulsivity predictors (i.e., negative urgency, lack or perseverance, lack of premeditation, sensation seeking, and positive urgency) significantly contributed to the variances in online risk-taking behaviours. Gender, age, and nationality were entered into the regression model in Step 1 to control for the potential influence of these demographic variables on the outcome. The results showed that only gender (β = -.230, p = .002) significantly contributed in predicting online risk-taking behaviours (R = .265, R^2 = .070, $R^2change$ = .070, F (3, 195) = 4.89, p = .003). Then, negative urgency was entered in Step 2. Again, gender is significant (β = -.224, p = .001) while other predictors were not statistically significant in this model (R = .290, R^2 = .084, $R^2change$ = .014, F (4, 194) = 4.46, p = .002). Next, lack of perseverance was entered in Step 3, and a similar pattern of results is obtained with gender (β = -.243, p = .001) and lack of perseverance (β = .163, p = .021) being the significant predictors, with R = .330, R^2 = .109, $R^2change$ = .025, F (5, 193) = 4.73, p = .001. In Step 4, lack of premeditation was entered, and resulted in an increase of R^2 with 3.3% variation in online risk-taking behaviours is explained by gender (β = -.249, p = .001) and lack of premeditation (β = .195, p = .007). A significant overall model was also obtained (R = .377, R^2 = .142, $R^2change$ = .033, F (6, 192) = 5.295, p = .001). Next, sensation seeking was entered in Step 5, resulting in the same significant predictors of gender (β = -.247, p = .001) and lack of premeditation (β = .201, p = .006). Model 5 is also statistically significant (R = .380, R^2 = .144, $R^2change$ = .002, F (7, 191) = 4.59, p = .001). Finally, at Step 6, all predictors were entered, and the addition of positive urgency yielded a significant model (R = .409, R^2 = .167, $R^2change$ = .023, F (8, 190) = 4.76, p = .001). Results also showed that gender (β = -.241, p = .001), lack of premeditation (β = .201, p = .006), and positive urgency (β = .159, p = .023) remained statistically significant even when other predictors were entered into the regression equation. Results of these analyses are summarised in TABLE 2 and Fig. 2 below.

Table 2 Prediction of Online Risk-Taking Behaviours from Impulsivity Domains

Predictors		R^2	R^2change	B	SE B	β
Step 1	Gender	.070	.070***	-3.299	1.063	-.230***
	Age			.029	.309	.007
	Nationality			.638	.669	.071
Step 2	Gender	.084	.014	-3.213	1.059	-.224***
	Age			.062	.308	.014
	Nationality			.626	.665	.070
	Negative Urgency			.411	.237	.119
Step 3	Gender	.109	.025*	-3.486	1.054	-.243***
	Age			.075	.304	.017
	Nationality			.272	.675	.030
	Negative Urgency			.374	.235	.109
	Lack of Perseverance			.610	.262	.163*
Step 4	Gender	.142	.033***	-3.570	1.037	-.249***
	Age			.092	.300	.021
	Nationality			.402	.666	.045
	Negative Urgency			.278	.234	.081
	Lack of Perseverance			.366	.273	.098
	Lack of Premeditation			.678	.250	.195***
Step 5	Gender	.144	.002	-3.536	1.040	-.247***
	Age			.081	.300	.019
	Nationality			.368	.669	.041
	Negative Urgency			.284	.235	.083
	Lack of Perseverance			.413	.282	.110
	Lack of Premeditation			.699	.253	.201***
	Sensation Seeking			.132	.196	.048
Step 6	Gender	.167	.023*	-3.454	1.029	-.241***
	Age			.130	.298	.030
	Nationality			.378	.662	.042
	Negative Urgency			.181	.237	.053
	Lack of Perseverance			.442	.279	.118
	Lack of Premeditation			.700	.250	.201***
	Sensation Seeking			.036	.198	.013
	Positive Urgency			.417	.182	.159*

Note: β values are the standardised regression coefficients of the regression analysis.
***p<.001, *p<.05.

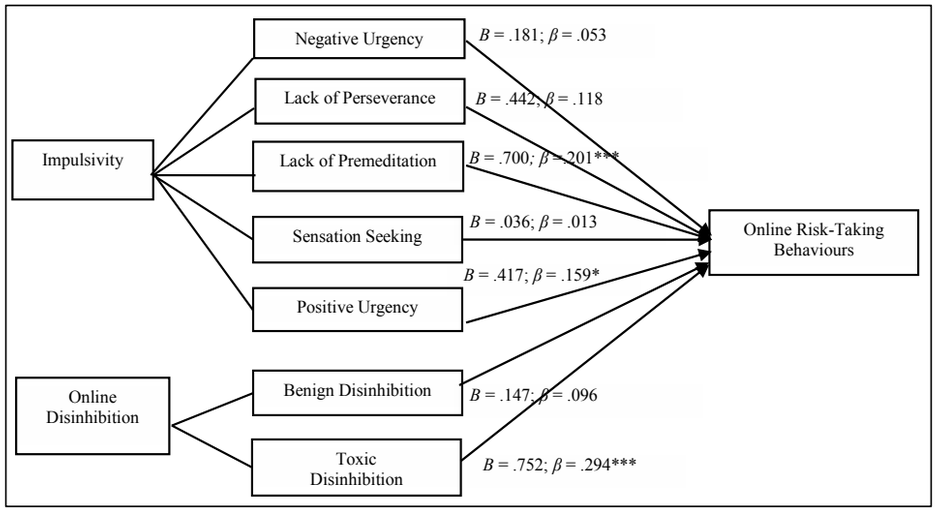

Figure 2 Unstandardised (*B*) and standardised (*β*) regression coefficients in the final model of the relationship between impulsivity and online disinhibition predictors and online risk-taking behaviours

In the second hierarchical multiple regression, online disinhibition predictors (i.e., benign and toxic) were examined with online risk-taking behaviours as the outcome. Similar steps were followed whereby gender, age, and nationality were entered into the regression model in Step 1, followed by benign disinhibition in Step 2, and toxic disinhibition in Step 3. The results showed that Model 1 was significant, F (3, 199) = 4.217, p = .006 (R = .244, R^2 = .060, $R^2change$ = .060) with gender (β = -.219, p = .004) as the significant predictor. Model 2 was also statistically significant, F (4, 198) = 5.008, p = .001, with both gender (β = -.206, p = .006) and benign disinhibition (β = .181, p = .009) were significant predictors of online risk-taking behaviours. Together, these predictors accounted for a total of 9.2% of the variance (R = .303, R^2 = .092, $R^2change$ = .032). Finally, Model 3, F (5, 197) = 7.577, p = .001, showed that the addition of toxic disinhibition explains around 16.1% of the variance of online risk-taking behaviours (R = .402, R^2 = .161, $R^2change$ = .069). When all predictors were considered jointly in the same regression model, gender remained a significant predictor of online risk-taking behaviours (β = -.164, p = .023). However, benign disinhibition was no longer a significant predictor (β = .096; p = .164) in this Model. Interestingly, toxic disinhibition was found to be a significant predictor of online risk-taking behaviours (β = .294; p = .001) even when other predictors were controlled. These results are summarised in Fig. 2 and TABLE 3.

Table 3 Prediction of Online Risk-Taking Behaviours from Online Disinhibition Domains

	Predictors	R^2	R^2change	*B*	SE *B*	*β*
Step 1	Gender	.060	.060***	-3.083	1.053	-.219***
	Age			.054	.305	.013
	Nationality			.438	.657	.050
Step 2	Gender	.092	.032***	-2.905	1.040	-.206***
	Age			.059	.300	.014
	Nationality			.657	.652	.075
	Benign Disinhibition			.275	.104	.181***
Step 3	Gender	.161	.069***	-2.314	1.012	-.164*
	Age			.030	.290	.007
	Nationality			-.072	.654	-.008
	Benign Disinhibition			.147	.105	.096
	Toxic Disinhibition			.752	.186	.294***

Note: *β* values are the standardised regression coefficients of the regression analysis.
***p<.001, *p<.05.

4.0 DISCUSSION

This study aimed at providing information on attitudes toward e-safety among the Millennials whose involvement and engagement are fostered in an increased reliance on technology. This aim is achieved by examining their attitudinal responses on impulsivity, online disinhibition, and online risk-taking behaviours. Results showed that the most significant impulsivity predictor of online risk-taking behaviours is lack of premeditation, which is in line with the literature that has demonstrated a consistent relationship between the two variables. For example, in their meta-analytic review, Berg et al. (2015) indicate that lack of premeditation predicts or correlates with risky behaviours such as increased frequency of alcohol or substance use, reactive aggression, suicidality, and non-suicidal self-injuries. One plausible explanation for this result is that lack of premeditation might be based on poor consideration of consequences that resulted from low levels of executive control (Phillippe et al., 2010), low self-control (Latzman & Vaidya, 2013), or high tolerance for punishment from maladaptive or risky behaviours (Berg et al., 2015). This inability to reflect on the consequences of an action, could, in turn, lead to making decisions without insight into possible choices or consideration of past outcomes.

Besides lack of premeditation, positive urgency is another significant impulsivity predictor of online risk-taking behaviours found in this study. This result is interesting because the concept of positive urgency was included only recently in the impulsive behaviour model, and thus, minimal research evidence is available (Berg et al., 2015). Nevertheless, in the few studies where this variable has been investigated, positive urgency has been demonstrated to be associated with problematic alcohol or substances use, problematic gambling, and borderline personality disorder traits (Berg et al., 2015; Cyders et al., 2010). Berg et al. (2015) posit that positive urgency may stem from an immediate desire to engage in highly rewarding activities. Since positive urgency is a measure that relates to emotional state, two possible explanations have been put forward by Berg et al. (2015). First, it is likely that affect has a key role in triggering impulsive behaviours, and second, individuals with poor emotion regulation skills might display various forms of impulsive behaviours. Therefore, Berg et al. (2015) suggested that negative and positive affectivity, as well as emotion regulation skills, need to be controlled to fully understand the nature of the relationship between urgency and risk-taking behaviours. Following from this suggestion, one promising avenue of future research may be to examine the cognitive or neural mechanisms underlying both urgency domains (Berg et al., 2015; Cyders et al., 2014).

Our results on toxic disinhibition as a significant online disinhibition predictor of online risk-taking behaviours are also consistent with the existing literature. This suggests that those who adhere to a more toxic disinhibition effect are more likely to engage in risky behaviours. Earlier research by Suler (2004) and Joinson (2007) has attributed the antecedents of toxic online disinhibition to anonymity, invisibility, asynchronicity, solipsistic introjection, dissociative imagination, and minimisation of status and authority. Later research has added new antecedents of disinhibition such as subjective norm and inner containment (Wu, Lin, & Shih, 2017) as well as perceived lack of repercussions (Udris, 2014). Of particular interest is the explanation provided in a recent study by Voggeser, Singh, and Göritz, (2018), which suggests that failure at self-control may lead to failure of noticing social cues, which, in turn, could lead to toxic communication patterns. The challenge of verifying the role and contribution of these antecedents to explaining disinhibiting behaviours is beyond the scope of this study. However, understanding these antecedents can result in the formulation and development of better policies and technologies, especially the ones related to legal, education, cybersecurity, telecom, and mobile applications.

Although not hypothesised, gender emerged as a significant predictor of online risk-taking behaviours in both regression analyses conducted. This is another striking result because there is evidence in the literature that gender does play an important role in explaining risky behaviours. For example, studies by Chiou and Wan (2006), Jensen et al., (2002), Kim and Kim (2012), Lau and Yuen (2013), as well as Leung and Lee (2012) reported that males tend to engage in riskier online behaviours such as sexual self-disclosure, online aided academic cheating, use of unauthorised softwares, and Internet addiction than do females. Similar results are obtained in the present study as we found male Millennials reported more online risk-taking behaviours compared to females (see Table 1).

This study is not without its limitations, and we acknowledge that several aspects warrant a careful interpretation of the results. First, with an unequal number of genders and a higher count of female respondents in this study, there will always be a possibility of gender differences that may influence the results. Furthermore, the majority of the participants in this study are from collectivistic cultures, and according to Martin (2011), people in these cultures tend to be somewhat high in uncertainty avoidance; hence, lowering the willingness to report or commit unethical behaviours. Therefore, care must be exercised when it comes to generalising the findings to the broader population. Second, as in other survey-based research, social desirability bias may ensue. Bernardi (2006) conducted a study involving people from various countries and found that the tendency of giving socially desirable responses decreased as the demography shifts into a more individualistic one. In other words, when faced with sensitive questions, there is a possibility of participants with a collectivistic orientation giving socially desirable responses instead of accurate answers. Here, the issue would be again on the extent of generalisation that could be made out of the study's results.

Lastly, there is no clear demarcation line when it comes to impulsivity and disinhibition. Previous studies (e.g., Reid et al., 2014) have argued that impulsivity is a complex construct with numerous approaches to measuring it. This is also the

case with disinhibition. Despite having different conceptual and operational definitions, both online and offline disinhibition may have converged somewhere along the lines, and to separate the two, studying only the phenotypical measure of disinhibition would not suffice. Hence, further studies using different types of measurements that can tap into various aspects of disinhibition are recommended. In short, future studies should take into consideration all these aspects, especially with regard to accounting for potential influencing variables such as culture, gender, and the dynamic nature of online interaction. Therefore, more research is needed to clarify how these variables may influence risk-taking behaviours.

5.0 CONCLUSION

This study was conducted because of the dearth of work on the Millennials' attitudes and online behaviours, particularly in the context of Industry 4.0 and the Industrial Internet of Things (IIoT). The findings showed that lack of premeditation, positive urgency, and toxic disinhibition are the aspects of impulsivity and online disinhibition that demonstrated the strongest associations with online risk-taking behaviours. It may, therefore, be suggested that these variables are the most relevant target areas for interventions that could modify risky behaviours in cyberspace, particularly where the future trends would be heading towards the gig economy and crowd-working. What remains unclear, however, is the nature of each variable's unique contribution to the broad psychopathology such as to conduct disorders, obsessive disorders, and psychosomatic disorders in these settings. Therefore, future studies should examine the contributions of these variables in the context of a wide range of covariates including socioeconomic factors and different types of gig economy workers. It is also worth examining the implications of these new forms of employment for occupational safety and health, both physically and mentally, as well as exploring the regulations, systems, and mechanisms that fit this fast-paced, unstable, unpredictable, yet socially-connected work environments.

The findings on gender are most interesting because although the number of male participants is less than females in this study, their online risk-taking behaviour ratings are still markedly significant. This result suggests that while interventions are essential for both genders, additional efforts to focus on male Millennial workers are required given their higher propensity to engage in risky behaviours than females. To this end, potential awareness and behavioural training interventions that are gender-specific are recommended and worth further experimentation and development. Taken these results together, this study has provided some insight into how Millennials perceive and behave online or in cyberspace. Future works are welcomed to further deliberate these issues and contribute to the existing body of knowledge on the online attitudes and behaviours of the Millennials in occupational and professional settings.

ACKNOWLEDGEMENT

The authors thanked Associate Professor Melissa A. Cyders, Dr Reinis Udris, and Dr Wilfred W. F. Lau for the permission to use the short version of the Urgency, Premeditation, Perseverance, Sensation Seeking, and Positive Urgency (Short UPPS-P) Scale, the Revised Online Disinhibition Scale, and Online Risky Behaviour Scale respectively. Gratitude and thanks are also extended to all participants in this study and to the Reviewers on their useful suggestions.

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Book:

Perez, A.K., Little, T.H., & Brown, Y.J. (1999). Safety in numbers. Itasca, IL: National Safety Council.

On-line Publication:

National Institute of Occupational Safety and Health. Sick Building Syndrome. www.niosh.com.my/safetytips.asp?safetyid=1 (accessed October 2004)

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