ORIGINAL ARTICLE

Assessing Process Safety Management Practices and Their Impact on Workers' Health in Negeri Sembilan's Glove Manufacturing Industry

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ABSTRACT

Introduction: Process Safety Management (PSM) elements have been an essential consideration, especially in the manufacturing industry, as an effective implementation of the elements could curb the hazards exposure among workers. This study seeks to evaluate the implementation of PSM elements which are Process Hazard Analysis (PHA) and Mechanical Integrity (MI) and their impacts on worker's health in glove manufacturing industry. **Materials and methods:** An analytical cross-sectional study was performed with 76 respondents from a glove manufacturing factory in Negeri Sembilan, Malaysia using a stratified random sampling method. A self-administered questionnaire was distributed to respondents through an online application. The acquired data was analyzed using SPSS Version 28. **Results:** The results showed that the PHA and MI were confirmed being implemented in the organization with overall mean of 2.80 and 2.83 respectively. Throughout 6 years of organization's establishment, 8 total cases were reported and recorded in the NADOPOD system pertaining to accidents and diseases. However, there was no statistically significant association between PHA with workers' health impact (r = -0.027, p = 0.817) and there was also no statistically significant association between MI with workers' health impact (r = -0.091, p = 0.436). **Conclusion:** This study concludes that there could be an indicator for future research to study all 14 PSM elements in depth and its' correlation with other health impact measurement related to medical condition.
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INTRODUCTION

Malaysia has made significant advancements in the manufacturing industry ever since it was first introduced in the 1970s and in the fourth quarter of 2021, the manufacturing sector has expanded moderately by 3.9%, with electrical and electronic, and optical products leading the way (9.2%), followed by transport equipment, other manufacturing and repair (4.9%) (1). However, the Manufacturing sector remained as the highest contributor to occupational injuries rate in 2021 at 2,297 cases (3.20 cases per 1,000 workers), based on the Occupational Safety and Health Act 1994 OSHA sector (Act 514) (2).

The glove manufacturing industry in Negeri Sembilan, Malaysia, is a significant contributor to the region's economic growth, providing employment opportunities and fueling industrial development (3). However, the inherent nature of the manufacturing processes in this industry, which often involve the use of hazardous chemicals and machinery, can pose significant risks to the health and well-being of workers (4). Proper implementation of Process Safety Management (PSM) practices is crucial in mitigating these risks and ensuring the safety of the workforce.

PSM has been an essential consideration in glove manufacturing plants that handle highly hazardous chemicals (HHCs), and the employer has the primary responsibility to protect workers from the adverse health effects of these chemicals. A highly hazardous chemical is defined as a substance that poses a significant risk of causing severe harm or even death to worker if inadvertently released or mishandled (5). In the glove manufacturing industry, these chemicals may include caustic cleaners, toxic paints, flammable solvents and other potentially hazardous substances (6). PSM implementation in any process plants is beneficial in terms of offering an insightful information for variety of control measures and positively influencing human factors with regards to safety. An incident or accident during the operation of a chemical processing plant could be identified, understood, controlled, and prevented by integrating the human factor with PSM (7).

Existing research has highlighted the critical role of effective PSM practices in the Malaysian manufacturing sector, underscoring the need to assess the implementation and impact of such practices in the glove manufacturing industry of Negeri Sembilan (4). Research has identified safety culture, encompassing the shared attitudes, beliefs, and behaviors of individuals and organizations, as a pivotal factor in determining the success or failure of safety initiatives within the manufacturing industry (4). Additionally, studies have emphasized the influence of leadership, organizational communication, and work environment on the psychosocial hazards faced by workers, which can significantly impact their overall health and well-being (8).

Variety of chemicals substances in gaseous and liquids form are heavily used in glove manufacturing industry and it is the duly responsibility of the employer to monitor all workers exposure to these highly hazardous chemicals. These hazardous substances could enter the body system of workers through inhalation, ingestion or through dermal exposure (9).

The existing studies have primarily focused on the health effects chemical exposure, particularly the prevalence of latex hypersensitivity among consumers, such as healthcare workers (10). However, there is a noticeable gap in the research exploring the chemical safety consideration for industrial workers who handle latex on a regular basis. While past studies have addressed the toxic, harmful and sensitizing properties of latex, there is limited understanding of the potential flammability, explosivity or other safety risks associated with its industrial use (11). PSM effectiveness depends on the implementation of the elements such as process safety metrics, management review, audit findings and workforce involvement (12). The implementation effectiveness for PSM elements is never studied for its correlation with the health impact of workers as the dependent variable measured thus this research study was conducted.

Effective PSM is a disciplined framework for managing the integrity of operating systems, safety-critical equipment, and safe work practices (13). It requires industries to execute suitable leading and lagging process safety metrics, encompassing various elements such as human factors, good design principles, recognized and generally accepted good engineering practices, engineering and administrative controls, and the integrity of operating and maintenance practices (13). This holistic approach to PSM is crucial for ensuring comprehensive chemical management, as it goes beyond the traditional Chemical Health Risk Assessment (CHRA), which may focus primarily on individual chemical hazards and their immediate health impacts.

The importance of integrating PSM and CHRA lies in the fact that hazards and risks are not equal, and there are multiple risks and consequences to consider. A structured and systematic approach to PSM, as described in the literature, can provide a framework for improving operational and process safety throughout the entire project life cycle, from design and construction to operation, maintenance, and decommissioning.

By incorporating PSM principles into chemical management practices, organizations can ensure a more comprehensive and risk-based approach to managing the safety and integrity of their operations. This integrated approach can help organizations identify and address potential process safety issues that may have been overlooked by a more traditional CHRA, thereby enhancing the overall safety and resilience of their operations (13,14,15).

Out of 14 PSM elements studied in the interrelation analysis, Process Hazard Analysis (PHA) and Mechanical Integrity (MI) were identified to have the highest interrelation with 12 others interrelated PSM elements (16). Thus, these two elements were identified as the critical and primary elements of PSM that studied in-depth for this research.

PSM implementation should focus on both PHA and MI while covering other elements of Employee Participation, Process Safety Information, Operating Procedures, Training, Contractor, Process Safety Startup Review, Management of Change, Incident Investigation, Emergency Planning Response, Compliance Audit and Trade Secret (17). The significance of this is to ensure workers have a safe and good work condition and ensure they are healthy and fit to perform their work without much risk to life. Therefore, these two elements are determined to be the critical elements of PSM which were used to study their implementation and the association with worker's health impact in glove manufacturing industry.

PHA is a systematic approach for identifying, evaluating and controlling hazards of processes involving hazardous chemicals where the analysis must be done during initial operational phase. While, MI element plays a significant role during constructing operational stages in system. Maintenance of all process control systems and critical equipment must be executed following engineering standards and codes. MI universally known as one of most effective element of a facility's PSM program implemented.

Therefore, this study aims to investigate the current state of PSM practices in the glove manufacturing industry of Negeri Sembilan, Malaysia, and to evaluate their impact on the health and safety of the workers.

MATERIALS AND METHODS

Data Sources and Participants

An analytical cross-sectional study was conducted among workers at the one of the world's largest glove manufacturing industry based in Malaysia. The factory is located in Nilai, Negeri Sembilan, a manufacturer of Latex Examination Gloves (Powdered and Powder Free) for the usage of medical practitioners. Nilai is a small town of the state of Negeri Sembilan which determined as a new township for rapid development of its economic activities mainly the manufacturing industry. The vibrancy of Nilai city had shown an increase volume of people in this town thus this study is most suitable to be studied here among workers in manufacturing industry.

The target population of this research consists of workers from four departments (compounding, production, QA laboratory, maintenance) which have higher risk of exposure to highly hazardous chemicals and heavy-duty industrial machineries with a total population of up to 95 at once throughout the day. Based on Krejcie and Morgan method (18), 76 respondents were recruited among the population workers who fulfil the predetermined criteria of working for more than one-year, full time, directly handling chemicals, tools, machineries and have never had any previous medical. Excluding participants with any prior medical conditions allows to isolate the effects of workplace safety practices from pre-existing health issues. This ensures that any observed health outcomes can be more directly attributed to the safety management practices being evaluated rather than confounding variables related to individual health histories.

A structured and validated questionnaire in English with Malay translation was distributed to each worker through Google Form (online). The questionnaire was sent for content validation to two experts from the Department of Environmental and Occupational Health at the Faculty of Medicine and Health Sciences, Universiti Putra Malaysia. Their feedback was incorporated into the questionnaire, leading to amendments based on the expert comments prior to data collection. This process ensures that the questionnaire is relevant and accurately reflects the constructs being measured. The questionnaire consisted of three section which were Section A, Section B and Section C. Section A contained questions on the information of social demographic information of respondents. Specifically, the variables collected are department, position, gender, race, education level and duration of employment.

Section B involved total of 22 questions on respondent's department details such as type of chemical handling, worker's awareness and knowledge on the PHA including training involvement and perception on the Standards of Exposure of Chemicals Hazardous to Health Regulations 2000 (USECHH Regulations 2000) compliance by employer. The USECHH is a set of regulations that govern the use and management of hazardous substances in the workplace (19). This regulation is focused on protecting the health of workers by establishing exposure limits, requiring the provision of personal protective equipment, and mandating the implementation of control measures to mitigate the risks posed by hazardous chemicals (20).

Section C consisted total of 18 questions on respondent's department details such as type of machineries handling, worker's awareness and knowledge on MI including training involvement and perception on the OSH Act 1994 compliance by employer.

Alternatives of 'Yes', 'No' and 'Maybe' was applied for each question in Section B and C. Four extra questions were included in Section B as researcher listed questions on the Chemical Exposure Monitoring (CEM) and Hazard Identification, Risk Assessment and Risk Control (HIRARC) reviews on the implementation, training, tracking and effectiveness study that also covered under PHA reviews section. CEM is an essential component of the USECHH Regulations 2000, which aim to measure and control chemical containment (21). The rationale for assessing CEM knowledge on PSM lies in the fundamental role of PSM in ensuring the safe handling and control of hazardous chemicals. PSM is a disciplined framework for managing the integrity of operating systems, safety-critical equipment, and safe work practices (13). It is a comprehensive management system that requires extensive documentation of the process design, maintenance practices, training, system changes, operational procedures, and other critical elements (22). Effective implementation and audits of the PSM system, along with continual improvement, are essential to ensure the safety of chemical operations (13).

The main objective of any safety management program, including PSM, is to reduce the risk of chemical hazards to a level that is as low as reasonably practicable. Accurate process safety information is a core requirement of a successful PSM system, as it forms the foundation for identifying hazards, conducting PHA, and developing effective risk control measures.

In addition, the secondary data was also obtained from the organization on workers' exposure to highly hazardous chemical at respective department as well as the occupational accident cases reported in Notification of Accident, Dangerous Occurrence, Occupational Poisoning, and Occupational Disease (NADOPOD) system by organization.

Statistical Analysis
A Cronbach's alpha coefficient test was conducted and the results shown the calculated Cronbach's alpha using SPSS for Section B of the questionnaire was 0.865 and Cronbach's alpha for Section C was 0.874 which considered acceptable. Data collected was analyzed by using statistical package for social sciences (SPSS) version 28.0. The study used descriptive method to analyze the demographic characteristics of respondents and the use of Spearman's Rho correlation for analyzing association between PHA and MI with workers health impact.

Ethical Clearance
This research was approved by the Ethics Committee for Research Involving Human Subjects with the reference number of JKEUPM-2023-252.

RESULTS

Socio-demographic Background
The mean age of respondents was 30.9 years (SD = 5.043) with majority of them were in range of 21 to 30 years old. As a whole, there were more males [n= 44, 57.9%] than females [n= 32, (42.1%)] had participated. Duration of working years of participants were highest at 72.4% working for 1 to 10 years with mean 7.6 years (SD = 4.88). Educational level reported respondents had secondary education background with 47.4% compared to tertiary, primary and no formal education background. Production department represented the majority of the respondents (61.0%). Junior executive level (43.4%) and middle executive level (42.1%) participated in completing the questionnaire compared to senior executive level. Table I presented the socio-demographic data of respondents and general information of employee.

Table I: Socio-demographic Data of Employee

Information	Frequency (N=76)	Percentage (%)	Standard Deviation
Gender			
Male	44	57.9	
Female	32	42.1	
Age (years)			5.043
21-30	43	56.6	
31-40	28	36.8	
41-50	4	5.3	
51 and above	1	1.3	
Working Experience (years)			4.880
1-10	55	72.4	
11-20	17	22.4	
21-30	3	3.9	
31 and above	1	1.3	
Educational Level			
No formal education	7	9.2	
Primary education	13	17.1	
Secondary education	36	47.4	
Tertiary education	20	26.3	
Department			
Production	47	61.0	
Compounding	14	18.2	
QA Laboratory	4	5.2	
Maintenance	12	15.6	
Position Level			
Junior Executive	33	43.4	
Middle Executive	32	42.1	
Senior Executive	11	14.5	

CONTINUE

Process Hazard Analysis (PHA) Implementation in Organization
The mean and standard deviation of the PHA's measures collected from the questionnaire Section B were calculated using SPSS and shown in Table II. The mean of the PHA measures implementation ranged between 1.33 (SD = 0.179) until 2.99 (SD = 0.115). The mean 2.99 demonstrated that majority of respondents (n= >70, above 90%) agreed that they conducted PHA review whenever new manufacturing processes such as new method being introduced to ensure no new hazards established and all of the recommendations had successfully reduced the existed risks. 2.99 mean value also represented that workers are aware of any incidents that occurred which resulted from inadequate health hazards consideration in PHA. The lowest mean is 1.33 was due to a distributed answer of 'Yes' (11.5%), 'No' (81.6%) and 'Maybe' (3.9%) collected from all respondents for variable respondents answered they experienced any health issues or symptoms that may be related to exposure to hazardous chemicals. Total mean score calculated for all variables in PHA Measures Implementation is 2.80 which shows high responds were obtained from the 'Yes' choice of answer and positive direction of PHA implementation at workplace.

Table II: PHA Measures Implementation

Item	Mean	Standard Deviation
Conduct Process Hazard Analysis on the raw materials used to identify potential hazards	2.95	0.322
Conduct Process Hazard Analysis review on new manufacturing processes	2.99	0.115
Identify and assess the potential risks associated with handling of chemicals	2.80	0.589
Acknowledge the consequences of mishandling chemicals at workplace	2.97	0.161
Awareness of Personal Exposure Limit for Chemical Exposure Monitoring in respective department	2.05	0.978
Received briefing by SHO regarding exposure limit for Chemical Exposure Monitoring	2.86	0.453
Using USECHH Regulations 2000 for conducting Process Hazard Analysis	2.68	0.522
Received training to identify potential chemical hazards in glove manufacturing process	2.88	0.431
Received training for immediate respons to any chemical-related incidets/accidents	2.88	0.431
Conduct Process Hazard Analysis at least 3 years once as required by DOSH	2.79	0.410
Recommendations from Process Hazards Analysis reviews been tracked	2.97	0.161
Recommendations from Process Hazards Analysis reviews successfully implemented	2.97	0.161
Recommendations from Process Hazards Analysis reviews successfully reduced the existed risks	2.99	0.115
Implementation of system to ensure process safety hazards continuosly monitored and reviewed	2.97	0.161
Adequate resources and support from management for process safety management implementation	2.87	0.472
Process Hazard Analysis process adequately minimize the potential health hazards associated with chemicals used in glove manufacturing process	2.97	0.161
Awareness on any incidents occurred resulted from inadequate health hazards consideration in Porcess Hazard Analysis process	2.99	0.115
Incidents related to inadequate health hazards consideration in Process Hazard Analysis process properly reported and investigated	2.88	0.399
Received training on potential health impacts associated with exposure to hazardous chemical used	2.87	0.340
Existing procedures for workers exposed to hazardous chemicals used are provided with appropriate medical attention	2.96	0.196
Experienced any health issues or symptons that may be related to exposure to hazardous chemicals	1.33	0.719
Agreed on the implementation of Process Hazard Analysis measures could help in identifying and reducing health problems risk associated with hazardous chemicals in glove manufactruing	2.95	0.225
Total Mean Score	2.80	

Mechanical Integrity (MI) Implementation in Organization

The mean and standard deviation of the MI's measures collected from the questionnaire Section C were calculated using SPSS and shown in Table III included the details of the variable analysis regarding implementation of MI. The mean of the MI measures implementation ranged between 1.38 (SD = 0.765) until 2.99 (SD = 0.115). The highest mean of Section C is 2.99 contributed from majority respondents (n= >70, above 90%) answered that they acknowledged the consequences of mishandling machineries at workplace resulting in cuts, lacerations, broken bones or amputation. The lowest mean of Section C is 1.38 which scored by variable respondents answered they experienced any health issues or symptoms that may be related to exposure to the use of equipment and machinery in glove manufacturing process. Similar to Section B, this variable showed lowest mean due to a distributed answer collected from respondents of 'Yes' (17.1%), 'No' (78.9%) and 'Maybe' (3.9%). Total mean score calculated for all variables in MI Measures Implementation is 2.83 which represented high responds were obtained from the 'Yes' choice of answer and positive direction of MI implementation at workplace.

Table III: MI Measures Implementation

Item	Mean	Standard Deviation
Awareness on the Mechanical Integrity requirements outlines in Process Safety Management standard	2.92	0.392
Existing written Standard Operating Procedure (SOP) outlines the Mechanical Integrity requirements for equipment and machinery at workplace	2.87	0.442
Acknowledge the consequences on mishandling machineries at workplace	2.99	0.115
Existing equipment inspection and testing programs to meet Mechanical Integrity requirements for equipment and machinery at workplace	2.97	0.115
Existing machinery Total Preventive Maintenance and repairing to meet Mechanical Integrity requirements	2.95	0.225
Received regular training on the Mechanical Integrity requirements for equipment and machinery at workplace	2.91	0.372
Existing procedures for equipment and machinery properly installed and commissioned following manufacturer's instructions and adhering to local codes and regulations	2.95	0.225
Agreed on Mechanical Integrity meausres implementation helaps reducing health risk problems associated wth the use of equipment and machinery	2.93	0.340
Existing documented system to track equipment and machinery inspections, repair and maintenance	2.87	0.442
Incidents related to equipment or machinery failures properly reported and investigated to determine root cause	2.95	0.225
Near misses related to equipment or machinery failures properly reported and investigated	2.80	0.566
Existing procedures to ensure equipment and machinery used do not produce excessive dust levels, fumes or other airborne that could impact worker's health	2.84	0.518
Existing procedures to ensure equipment and machinery used do not pose risk of physical injury to workers	2.88	0.433
Existing procedures to ensure workers properly trained on potential health impacts associated with exposure to hazardous materials emitted from equipment and machinery	2.97	0.161
Existing procedures to ensure workers exposed to hazardous materials emitted from equipment and machinery are provided with appropriate medical attention	2.97	0.161
Existing procedures to ensure workers injured due to equiment and machinery failures are properly treated and rehabilitated	2.97	0.161
Experienced any health issues or symptoms that may be related to exposure to the use of equipment and machinery in glove manufacturing process	1.38	0.765
Agreed on the implementation of Mechanical Integrity measures could help in identifying and reducing health problems risk associated with hazardous materials in glove manufacturing	2.86	0.453
Total Mean Score	2.83	

DISCUSSION

Relationship between Socio-demographics and PHA/MI

The results showed that majority of respondents were male compared to female which throughout observation it aligns with the selected departments as Production and Maintenance were dominated by male workers as it involves medium to high duty routine jobs carried out daily. It is widely believed that "Manufacturing Industry" refers to "Men's Industry", meaning that this sector employs more men than women due to this industry nature of including more physical labor, technical jobs and irregular work schedules (17).

Majority of the respondents are from the age category of 21 until 30 years old (56.6%) which contributed to high percentage of respondents have a working experience between 1 to 10 years only (72.4%). The findings indicate that adequate information have been collected from young workers at majority which proved that they were actively engaged and participated in organization program or any conducted studies that related to this industry. The high value of average mean of 2.82 for working years and PHA/MI shows that respondents' answers indicates a strong relationship between variables. It is believed that workers who have been in manufacturing industry for a longer period of time tend to gain more experiences, awareness, participation and knowledge in variety of areas including the PHA and MI elements of PSM.

Minor percentage of senior executive participated (14.5%) in this research is due to low appointed for senior position level at these four departments which also contributed to low percentage of respondents that are 41 years old and above. However, middle executive and senior executive contributes to the higher level of safety awareness and maturity (23). Findings shows high average mean value for the variables (2.81%) indicates that the relationship between position level and PHA/MI existed strongly. It indicates that workers with higher job level or status in this industry are someone who are more experienced and play better and significant role in PSM.

Respondents with no formal education had the highest mean which offered from this observation, a weak relationship strength with the PSM elements implementation as educational levels increased. A positive relationship between education and accident frequency as workers with higher education tend to possess superior abilities which broaden their scope of responsibility at work, thus increasing the risk of accidents due to incompliance of safety practices (24).

Health Impact / NADOPOD Reported Cases
Since its establishment in 2017 until 2022, a total of eight cases (Table IV) were reported in the NADOPOD system by the organization's Safety and Health Officer. More than 30 days of medical leave (MC) and hospital admissions were recorded, which summarizes all confirmed diagnosed injuries and diseases. The NADOPOD system contains all the notified information, affected person information, occupational disease, occupational accident, poisoning details and thorough description of work or main root cause that led to the occupational disease and accident occurred. Notification of occupational accidents and diseases plays a crucial role on the hazard identification, early warning or detection, appropriate prevention and best treatment of the related reported cases in order to avoid the same incident from happening again. All these criteria in NADOPOD are well suited for a study of workers' health impact that implied in the organization as it covers all the elements of PSM implementation and compliance during the investigation carried out.

Table IV: JKKP8 Data for 6 Previous Years

Year	JKKP8, NADOPOD (Reported Cases)
2017	1
2018	2
2019	2
2020	1
2021	1
2022	1
TOTAL REPORTED CASES	**8**

Process Hazard Analysis (PHA) Implementation in Organization
More than 90% of respondents agreed that PHA measures were practiced and conducted for the existing and when newly introduced raw materials or process and also during potential risks identification in handling chemicals in manufacturing. A good system and standard operating procedures (SOP) were said to be existed and successfully implanted in monitoring the process safety hazards and in ensuring workers that exposed to hazardous chemicals are properly monitored and provided with appropriate medical attention. SOPs may be created in accordance with a process or procedure, hazardous chemical classes or individuals, or any other approach that is reasonable and addresses the health and safety issues of an experimental protocol (25).

Trainings received by respondents showing a positive implementation of PHA measures in manufacturing with majority, with above 85% of respondents had answered they attended training regarding potential chemical hazards identification, immediate respond to chemical-related accidents, potential health impacts associated with hazardous chemicals and briefing on the CEM's exposure limit. This positive contribution is significant in raising awareness regards to their Personal Exposure Limit and any incidents occurred which resulted from inadequate health hazards consideration during PHA review. Giving employees training on chemical safety at work has a lot of advantages as a successful training will lessen the likelihood of a serious incident involving dangerous chemicals (26). Respondents also have a high level of the consequences of mishandling chemicals at workplace acknowledgement.

The study also showed that more than half of the respondents (n > 38) have a high awareness of and compliance with regulatory requirements. They use the industry-standard USECHH Regulations 2000 to conduct PHA and follow the PHA method, including conducting HIRARC at least once every three years. Investigations of incidents related to insufficient consideration of health hazards were also carried out. The USECHH Regulations of 2000 established standards for chemical exposure and sets out requirements for personal protective equipment, monitoring of chemical exposure, and medical and health surveillance that shall be obeyed by all chemical users or industries (27). High compliance rates were shown in terms of PHA review's recommendations were successfully implemented, tracked and effective in reducing the existed risks in the organization. Management was said to successfully in providing adequate resources and supporting the PHA implementation by 92% respondents. Lack of knowledge might affect people or organization's compliance on the regulations and it reduces the awareness of people regarding the issues (28).

In this study, workers responded to either 'Yes' (n=11, 14.5%), 'Maybe' (n=3, 3.9%) and 'No' (n=62,81.6%) when being asked either they ever experienced any health issues or symptoms that they believed it may be related to the exposure to hazardous chemicals. Respondents with 'Yes' came from the similar person in organization's 8 reported cases and the rest with history of non-occupational asthma and allergic. Respondents with 'Maybe' answer was determined to be not sure either the symptoms they previously faced were related to hazardous chemicals exposure or other factors. In conclusion, PHA measures implementation in organization are successful in past and current with the overall mean of 2.80.

Mechanical Integrity (MI) Implementation in Organization

The questionnaire listed several questions regarding the SOP either in placed or not in the organization which resulted in more than 90% of respondents agreed on the existing procedures for installation and commissioning following manufacturer's instructions, equipment and machinery do not produce excessive dust levels, fumes or other airborne that could pose risk of injury to workers. 97% respondents confirmed that they were properly trained on potential health impacts associated with exposure to hazardous materials emitted from machinery and confirmed existing of procedures that workers exposed to hazardous materials or injured due to equipment and machinery failures are properly treated and rehabilitated. This is because of major accidents frequently result from a chain of events that includes some prior behaviors and mistakes. A study conducted also highlighted the significance of including features in automation systems that enable human support to make up for technological shortcomings (29).

Outcomes of the questionnaire showed that respondents have a high awareness and compliance of MI measures with result collected above 90%. Most of them have high awareness on the MI outlines in PSM system and they acknowledged the consequences of mishandling machineries at workplace. It aligns with data showed that 73 respondents (96%) have received regular training on the MI requirements for equipment and machinery at workplace. Plus, positive reinforcement could be achieved through the implementation of administrative control measures such as training, equipment buyoffs and safe work practices. It is effective to reduce equipment incidents by establishing safety programs that integrate various organizational units because these integrations foster a better teamwork and workplace commitment. High compliance rate at above 90% responded for the existing of inspection, testing programs, Total Preventive Maintenance (TPM) and documented system was implemented to track and monitor all activities for machineries. Similar to PHA measures, all incidents and near misses related to equipment or machinery failures were properly reported and investigated thus it complied to the MI implementation requirements. Near misses comprise the lower portion of safety pyramid that these occurrences have the potential to cause loss but do not (26).

MI implementation benefiting the manufacturing by portraying a safer plant for every worker to be protected. Catastrophic failures are one of critical impact that resulted from MI measures failure. Machinery safety considers a machine's ability to carry out its intended function throughout its life cycle when risk has been sufficiently minimized.

From this study, respondents answered 'Yes' (n=13, 17.1%) when being asked either they experienced any health issues that they believed it may be related to the use of equipment and machinery which tallied with organization's reported cases and the rest with history of non-occupational injuries that not due to machineries failures. Respondents with 'Maybe' answer was determined to be unsure of their decision either the symptoms faced are related to hazardous chemicals exposure or other factors and might end up with self -interpreted and self-diagnosed as occupational disease. In conclusion, MI measures implementation in organization are successful in past and current with the overall mean of 2.83.

Association between Process Hazard Analysis (PHA) Implementation and Worker's Health Impact

The result shows that there was no statistically significant association between PHA implementation and workers' health impact where $r = -0.027$, $n = 76$, $p > 0.05$. The result indicated that this element of PHA has negative direction with workers' health impact. This outcome showed a result that contradicted with a study conducted where PHA had contributed significantly towards increasing the understanding of safety requirement among workers in manufacturing industries in Malaysia and reducing the occupational accidents related to human factors in handling processes (30). A study conducted in Taiwan also produced a good strength of relationship between PHA and explosion in pesticide plant causing occupational injury and fatality (31).

For more than 50 years, PHA or could be called as Hazard Identification and Risk Assessment (HIRA) have been performed formally in progressively better ways. During this time, techniques like What-If Analysis and HAZOP have been created and improved. However, a gap discovered 20 years ago is still present in the majority of PHA carried out globally in which this PHA typically do not carefully examine the errors that could happen during start-up mode, shutdown mode, and other irregular or abnormal modes of operation. Even though the process or plant may only be in that mode of operation for 1 to 5% of the time per year, the majority of catastrophic accidents still happen during non-routine operations which is about 75% most of the time. Most PHA/HIRA concentrate on normal mode of operation rather than the most dangerous mode of operation (32). Thus, this suggested that less reported cases notified was due to employers focusing on post-accident for routine operations only and not many on non-routine operations that shows no relationship between these variables studied in this research.

Important characteristics of a fully compliant PHA include an excellent team leadership and a PHA scribe that fully qualified in every aspect of a Best Practice PHA, including how to effectively manage and record the PHA, are required. Operators, operations engineers, higher level management and other team members as required who have the most expertise and experience.

Involvement and implementation of PHA at where each employee could have access to underlying details and current process safety information as needed, current, understandable, precise operating procedures and thorough comprehension and coverage of human factors and facility siting issues.

Association between Mechanical Integrity (MI) Implementation and Worker's Health Impact

The result shows that there was no statistically significant association between MI implementation and workers' health impact where $r = -0.091$, $n = 76$, $p > 0.05$. The result indicated that this element of MI has negative direction with workers' health impact. A study conducted observed the weakest correlation of management safety practice towards compliance of safety behavior among academicians compared to strong correlation of job safety and safety program variables instead. The main conclusions of the study showed that job safety and safety program policies, which were two independent variables, had a significant impact on compliance with safety behavior. On the other hand, academicians in educational field did not significantly associate management safety practices with compliance safety behaviour (33).

Any organization should give serious consideration to workplace safety. The management must make sure that the workplace is secure for the workers. The entire organization, including the employees, is accountable for occupational safety, not just the management. The literature on occupational safety demonstrates a direct or indirect relationship between workplace safety and employees' safety behaviors (34).

The FMA adopts a prescriptive approach to safety elements that includes risk-based inspections, the registration of factories and machinery, specifications for hoisting machines, and pressure vessels. The crucial elements of manufacturing industrial safety are not sufficiently covered. The superseding OSHA 1994 uses a self-regulatory approach and places a strong emphasis on the development of safety management that tends towards the general occupational domain. The safety of manufacturing operations, which go beyond personal safety to include process safety and asset integrity, is not adequately addressed by the safety and health laws (35). Thus, a relationship between MI is not significant to be directly relate with the cases of occupational accidents in organization.

Concluding Remarks

While this study may not be able to demonstrate that PSM implementation had significantly lower rates of occupational injuries and illnesses, this could be attributed to the focus of the current study on only two PSM elements—PHA and MI. Furthermore, reliance on NADOPOD data as a measure of health impact might have limited the ability to detect more subtle improvements in worker health related to PHA/MI. One limitation of this study is the potential for selection bias due to the exclusion of workers with pre-existing medical conditions. While this exclusion aimed to isolate the effects of workplace safety practices (PSM), it may lead to an underestimation of the true impact of workplace hazards on the overall workforce's health, as workers with pre-existing conditions might be more vulnerable. This also limits the generalizability of the findings to the entire population of glove manufacturing workers, as the study only represents a subset of healthy workers. To fully understand the intricate relationship between safety management and worker well-being in the glove manufacturing industry, future research should consider a broader range of PSM elements and utilize more sensitive health indicators. Therefore, future studies should specifically consider studying all 14 PSM elements in depth and their correlation with comprehensive health impact measurements, including those related to specific medical conditions, to provide a more thorough understanding.

The chemical industry is subject to a comprehensive set of regulations and standards aimed at safeguarding the immediate safety of workers as well as mitigating the long-term health implications associated with chemical exposure. While existing frameworks, such as the Control of Industrial Major Accident Hazards 1996 (CIMAH) and USECHH Regulations 2000, provide a clear structure for addressing acute safety risks and chronic health effects, respectively, the process safety discipline has traditionally focused more on the prevention of immediate incidents and accidents, without fully considering the long-term health consequences of chemical exposures (14, 22).

To address this gap, it is crucial to highlight the rationale for integrating chemical safety and chemical health considerations in the study of process safety. PSM systems must go beyond the prevention of acute injuries and immediate accidents, and also account for the potential chronic health effects of chemical exposure. This is particularly important as many hazardous chemicals exhibit physical properties that can lead to long-term health consequences, even in the absence of an acute incident (14, 20, 22).

The implementation of a comprehensive Hazardous Materials Protection Program, encompassing a hazardous materials communication program, a comprehensive occupational health hazard assessment program, and a chemical emergency response preparedness program, can effectively control workplace hazards, prevent accidents, and protect worker health and the environment (20).

CONCLUSION

In conclusion, this research discovered that the PHA and MI were confirmed being implemented in this glove manufacturing industry with the overall mean of 2.80 and 2.83 respectively. Most workers have awareness, high compliance rate, received and attended trainings and practices the PSM elements diligently in this organization. However, it was found that there were no statistically significant association between PHA with workers' health impact (r = -0.027, p = 0.817). There were also no statistically significant association between MI with workers' health impact (r = -0.091, p =0.436). Effective and comprehensive PSM is performance-based and therefore all 14 elements of PSM should be studied in depth instead of only 2 elements (PHA and MI) or different dependent indicator tools should be studied and analysed instead of referring the reported cases by organization as representative for workers' health impact such as Loss Time Injury (LTI) and turnover rate due to medical condition. In future, researcher also might want to study on the implementation of PSM elements' correlation with Knowledge, Attitude and Practices (KAP) among workers in several different industries.

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