Article Review

Process Safety Management as A Sustainable Safety Process in Managing Chemical Accidents in Malaysia: A Systematic Literature Review

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ABSTRACT : *The level of chemical accidents in Malaysia's Chemical Process Industry (CPI) is very worrying as the accidents occur every year. Thus, a sustainable safety process is necessary to minimize such unwanted events. However, studies regarding the safety process practice review in CPI are insufficient. Therefore, a well-conducted Systematic Literature Review (SLR) is considered a practical solution for keeping the practitioners on a row of the current safety process. Hence, this article reviewed the effectiveness of the process safety management (PSM) system based on PSM elements in CPI in Malaysia. Guided by the PRISMA Statement (Preferred Reporting Items for Systematic reviews and Meta-Analyses) review method, the SLR from the Science Direct, Web of Science, and Scopus databases identified six related studies in Malaysia. As a result, several authors highly implemented the Process Safety Information (PSI) element. Meanwhile, Process Safety Information Management System (PSI4MS) was a popular tool to drive the PSM system. Perhaps, this review article is a guideline to manage safety chemical accidents in Malaysia.*

Keywords - *Chemical Accidents, Safety Process, Systematic Literature Review*

1.0 INTRODUCTION

Malaysia has evolved rapidly from a commodities-based economy into a technology and engineering hub. As a result, various job hazards will be formed, especially those working in chemical processing industries, and the risks associated with chemical accidents will also increase. A chemical accident is an uncontrolled event where fire, explosion, uncontrolled release of toxic chemicals lead to death and injury to many people in a disaster area or cause great damage to property and the environment. These incidents can be sudden and acute or of slow-onset if a 'silent' release of toxic chemicals in a plant can range from small to large-scale emergencies. One of the most catastrophic chemical release accidents since 1991 was the May 7 fire disaster, which occurred at a fireworks factory called Bright Sparklers in Sungai Buloh, Selangor. The accident killed 26 lives, wounded

103 victims, and left an indelible mark on family members and residents (Ying & Ying, 2020). This tragedy is still fresh in mind for some residents, even though it was three decades ago. The accident warrants the parties involved and stakeholders to take more stringent safety efforts. The safety process is one of the safety measures in preventing chemical incidents and accidents. During this millennium, the number of accidents related to the release of chemicals has been steadily increasing, although safety and health awareness and education have been upgraded and exposure to industries has increased. Based on the Annual Report presented by Social Security Organization (SOCSO), 1415 cases of industrial accidents were reported in 2018 (2018 Annual Report, 2018). Hazardous chemical accidents include explosive and non-explosive materials, radiation, flying fragments, and other unclassified materials and substances. In addition, 190 cases were exposed to or in contact with harmful substances, while 127 cases were causing disease from chemical agents.

A safety management system related to the mitigation measure is the Process Safety Management (PSM), which can restrain process loss through appropriate controls of hazard of the process. PSM is considered a guideline to enhance the effectiveness of technical solutions and contribute to the mitigation measures of chemical accidents. According to Aziz & Shariff (2017), the PSM programme as stipulated by the US Occupational Safety and Health Administration (OSHA), Code of Federal Regulations (CFR) Chapter 29, Section 1910.119 in 1992. There are 14 elements in PSM, including Employee Participation (EP), Process Safety Information (PSI), Process Hazard Analysis (PHA), Operating Procedures (OP), training, involvement of contractor, Pre-Startup Safety Review (PSSR), Mechanical Integrity (MI), Hot Work Permit (HWP), Management of Change (MOC), Incident Investigation (II), Emergency Planning and Response (EPR), Compliance Audits (CA), and Trade Secret (TS). All the elements were predicted to prevent some deaths and serious injuries reports five years later, and twice that by subsequent years within five years. Implementing the PSM system to prevent major industrial accidents resulted in various positive effects. For example, in Korea, the number of major industrial accidents, including fatalities, has decreased, and productivity has been increased, and product quality after seven years of PSM implementation since 1996 (Kwon, 2006). This research was also supported by Shanmugam & Razak, (2021) and claimed that the PSM programme was practical and suitable to be implemented under the PSM mitigation measures in Malaysia.

In particular, inadequate and improper enforcement of PSM elements such as PHA, training, and EPR has been identified as the top three PSM elements contributing to most of China's accidents (Zhao, Suikkanen, & Wood, 2014). Another study also supports the above statement. Failure Knowledge Database (FKD-Japan), and Accident Reporting Information Analysis (ARIA), the most common accident contributors to process failure have been identified as failure of PHA (19 %), OP (17 %), employee participation (12 %), training (11 %), MOC (9 %), and MI (9 %) (Bakar et al., 2017). In parallel, some researchers have critically raised these PSM issues and the importance of implementing proper PSM elements in industries. A study of dust explosion incidents in Malaysia for powder manufacturing industries by Ahmad, Ismail, & Othman (2017) recommended that PSM elements such as PHA, training, and EPR should be seriously enforced by the government and local authorities. The company needs to improve its understanding of risk mitigation and control in its work process. Local authorities should review their stakeholders' operating procedures and discuss how to upgrade and implement the PSM elements. In addition, a study of oil & gas and chemical manufacturing industries in the United States by Behie et al. (2020) issued the level of effectiveness on PSM implementation as the number of accidents in this industry was still high. They argued the factors that caused current major incidents and measures that could have an impact on improving the effectiveness of process safety programs. They proved that PSM was the main factor that caused current major incidents such as lack of process safety training, knowledge and practices among workers, and ineffective emergency response plans. This indicates a more holistic approach to implementing effective PSM programs. All these examples show the importance and influence of the PSM system in managing chemical accidents.

The research journey on chemical accident mitigation measures is still far from reaching the finish line. Therefore, this study aims to review the effectiveness of the PSM system based on PSM elements in CPI in Malaysia. PSM contributes to CPI in eliminating or reducing hazards in managing chemical accidents in Malaysia. The Malaysian CPI is of particular interest as the industry contributes to the accident rate in Malaysia. Therefore, the implementation of a PSM system will effectively eliminate and reduce the hazards that contribute to the risk of chemical accidents.

2.0 METHOD

Four stages are involved in the Systematic Literature Review (SLR) process, including identification, screening, eligibility and inclusion. In addition, the inclusion and exclusion criteria steps are also included in the screening process. The reference management software Endnote X7 (Thomson Reuters, New York) was used to sort the records. Finally, the reviewers used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) adopted from Page *et al.* (2021).

2.1 Databases Search Strategy and Identification

Processes were carried out in early August 2021 for the databases search strategy. Based on previous studies and articles, PSM-related keywords were used. Articles were collected through selected search strings from the Science Direct, Web of Science, and Scopus databases. The keywords are such as: "process safety management" OR "safety management system" AND "chemical process industry" OR "chemical industry" AND "chemical accident" OR "chemical disaster". At this stage, only journal articles written in English and published until the year 2020 were selected. According to the specified keywords and search strings, a total of 863 research article records were identified. Our databases search found that Science Direct yielded 738 records, Web of Science yielded 113 records, and Scopus yielded 12 records. During the identification stage, 49 duplicate article records were removed. Thus, 814 records passed to the second stage.

2.2 Screening

The second stage was screening. At this stage, 263 title records and 530 abstract records were removed. In addition, titles and abstracts that did not meet the criteria, such as not related to the PSM elements or the chemical accidents in CPI, reviewed the study and clearly described the case studies other than Malaysia are excluded. Finally, 21 records were moved to the third stage.

2.3 Eligibility and Exclusion Criteria

The third stage was eligible. From 21 records, 15 records were removed according to the inclusion and exclusion criteria. Only articles with empirical studies that related to the implementation and application of PSM elements and explained the PSM performance in managing chemical accidents case studies in Malaysia were selected. According to McLeod, Payne, & Evert (2016), empirical papers should be classified as qualitative, quantitative, and mixed methods. One out of 15 records were found without full text although the request was sent through ResearchGate social networking site request and email to the authors. Six records were discovered from the case studies done other than Malaysia such as Japan, Pakistan, BP Texas City, Bhopal, Japanese FKD, and the US, one record indicated where the case study was not in CPI, two records were related to Inherently Safer Design, two records were from the review papers, two records were not mentioned the PSM elements, and one record not performing any case study. Finally, six records of full articles were extracted and analyzed. All these steps were mentioned in the PRISMA flow diagram in Fig. 1.

2.4 Included

At this stage, only articles with titles, abstracts, and full texts after the inclusion and exclusion process and meeting the criteria were included and reviewed. Then, the quality assessment continued by reviewing the entire text of screened studies. The table was developed from the included articles by mentioning the authors' names, year of publication, type of PSM elements, a field of case studies, measures, and outcome measures. Those data will finally define PSM performance in managing chemical accident cases in Malaysia as a lesson from the past event.

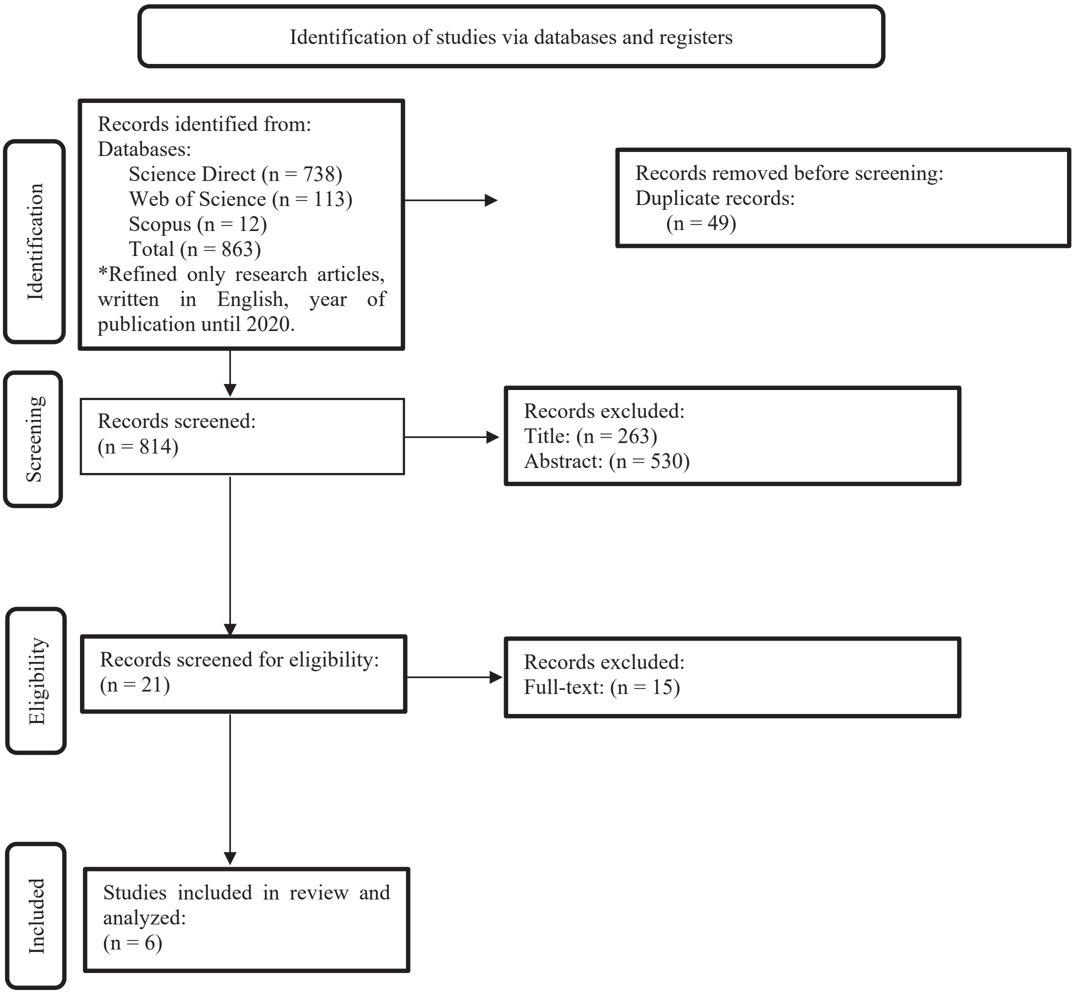

Figure 1 The Flow Diagram of the Study Adapted from Page *et al.*, (2021)

3.0 RESULTS

3.1 Results of the Search

Based on the keywords stated in the methodology, all six selected articles were published in 2003, 2009, 2014, 2015, and 2016. Field of case studies involved Chemical Process Industries (CPI) was from Carbon Dioxide (CO2) hydrocarbon absorption system pilot plant, LPG treating unit (LPGU) of oil and gas refinery, and High Gravitational Natural Gas Pilot Plant (HGNGPP). Meanwhile, type of PSM elements involved was Incident Investigation (II) (Shaluf, Ahmadun, & Said, 2003), Process Hazard Analysis (PHA) (Shariff & Leong, 2009), Process Safety Information (PSI) (Aziz, Shariff, & Rusli, 2014), and (Aziz, Shariff, Rusli, & Yew, 2014), involvement of contractor (Majid, Shariff, & Rusli, 2015), and Emergency Planning & Response (EPR) (Majid, Shariff, & Loqman, 2016).

Based on the readings, all the authors aim to establish, develop, and construct some specific tools or techniques to improve safety performance in workplaces using the elements from process safety management (PSM). The authors began their articles in the methodology sections by illustrating and explaining the development of safety performance frameworks or flowcharts based on PSM requirements and compliance. Frameworks or flowcharts are specifically shown to guide chemical industry practitioners in establishing a practical working process to improve the effectiveness of the PSM system. The development of these frameworks or flowcharts was eventually being tested in case studies to evaluate the safety performance in real and actual situations in CPI in Malaysia. Based on six selected articles, some of the authors came out with several specific tools such as developing a Process Safety Information Management System (PSI4MS) (Aziz, Shariff, & Rusli, 2014), and (Aziz, Shariff, Rusli, & Yew, 2014), and Emergency Planning & Response (EPR) prototype model (Majid, Shariff, & Loqman, 2016), and a Contractor Management System (CoMS) (Majid, Shariff, & Rusli, 2015), All findings were summarized in Table 1.

3.2 PSM Elements

There are 14 elements in the PSM system stipulated by the US Occupational Safety and Health Administration (OSHA), Code of Federal Regulations (CFR) Chapter 29, Section 1910.119 in 1992, which are Employee Participation (EP), Process Safety Information (PSI), Process Hazard Analysis (PHA), Operating Procedures (OP), training, involvement of contractor, Pre-Start Up Safety Review (PSSR), Mechanical Integrity (MI), Hot Work Permit (HWP), Management of Change (MOC), Incident Investigation (II), Emergency Planning and Response (EPR), Compliance Audits (CA), and Trade Secret (TS). However, only five elements were found in the literature in this review study, which was Incident Investigation (II), Process Hazard Analysis (PHA), Process Safety Information (PSI), involvement of contractor, and Emergency Planning & Response (EPR).

The literature found that the Incident Investigation (II) element was important to define the causes of the accident in the Chemical Process Industry (CPI). A case study by Shaluf, Ahmadun, & Said (2003) at the refinery in West Malaysia reported that hazardous gas named hydrocarbons escaped to the atmosphere and caused a fire due to a failure of the existing system. The conditions exceeded the existing design conditions. Pressure and temperature have exceeded the design limits of the system. The system could not cope with the resultant forces, and the flange joints downstream of the relief valves were suddenly opened. The management called for an investigation into the causes of the incident, a summary of the errors that led to the accident. Three errors were identified that caused the incident to occur. The main cause of the incident was technical and operational errors. Indeed, modification on project specification has supported the incident. A thorough investigation into this tragedy has been concluded a lack of knowledge of the project management and lack of follow-up by the management contributed to technical and operational errors. Thus, the II element in the chemical industry could efficiently guide the management to encounter the incidents from happening again.

Table 1 Descriptive Analysis of Included Articles for the Systematic Literature Review on the Implementation of the PSM Elements Based on Case Studies in Malaysia

No	Authors (Year)	Type of PSM elements	Field of case studies	Measures	Outcome Measures
1.	Shaluf, Ahmadun, & Said, (2003)	Incident investigation (II)	Refinery	Errors of incident	Identify the causes of incidents
2.	Shariff & Leong, (2009)	Process hazard analysis (PHA)	Hydrocarbon fractionation plant	Risk of an Inherently safer design	Identify the potential risk of unwanted events
3.	Aziz, Shariff, & Rusli, (2014)	Process safety information (PSI)	LPG treating unit (LPGU) of oil and gas refinery	Hazard and risk	Manage and control hazards
4.	Aziz, Shariff, Rusli, & Yew, (2014)	Process safety information (PSI)	Carbon dioxide (CO_2) hydrocarbon absorption system pilot plant	Manage process chemicals, technology, and equipment	Organize strategies to manage documentation, communicate information, and written program
5.	Majid, Shariff, & Rusli, (2015)	Involvement of contractor	High Gravitational Natural Gas Pilot Plant (HGNGPP)	Contractors' management system	Minimize and prevent accidents involving contractors
6.	Majid, Shariff, & Loqman, (2016)	Emergency planning & response (EPR)	Oil and gas refinery	Plan and implement ERP	Track and manage better EPR

A study by Shariff & Leong (2009) explained that the inherent risk of all streams of a hydrocarbon fractionation plant causing an explosion was assessed and evaluated using Inherent Risk Assessment (IRA) and integrated with a simulator process design. To estimate the risk, consequences and probability models developed in MS Excel were used. This spreadsheet-based tool is integrated with a process design simulator for process data to quickly and efficiently estimate risk. This assessment shows the implementation of the process hazard analysis (PHA) element in the PSM system. In the reported case study, a catastrophic rupture of a 300 millimeters diameter pipe resulted in a leakage of hazardous gas known as a hydrocarbon. Five out of 27 streams were analyzed based on the inherent properties of the chemicals used and the process conditions of the design. This assessment would influence the probability, the consequence (overpressure) of the explosion incident and the calculation of the overall frequency (F) of the event, as well as the capability of predicting the number of fatalities. According to the assessment, all the calculated risks are below the intolerable region set by Malaysian and thus, confirmed that stream design meets the Malaysian limits.

Process Safety Information (PSI) was most popular and identified in the literature by Aziz, Shariff, & Rusli (2014) and Aziz, Shariff, Rusli, & Yew (2014). It provides organized strategies for document management, conveys information and written programs for maintaining, revising, and updating related information. They developed a technique capable of systematically transforming information into a computer database prototype known as the Process Safety Information Management System (PSI4MS). A case study was conducted using real data from the LPG treating unit (LPGU) of oil and gas refinery Plant X in Malaysia, involving hazardous chemicals such as hydrogen sulfide using the Piping and Instrumentation Diagram (P&ID) (Aziz, Shariff, & Rusli, 2014). All the requirements are managed and monitored by PSI4MS using data captured through digital forms that can be stored in a centralized database involving process chemicals, technology, and equipment that must fulfill the compliance status.

Furthermore, authorized personnel can always be alerted to sufficient process information, covering the processes that need to be compiled to ensure the hazard control and risk reduction program is accomplished. Meanwhile, a case study by Aziz, Shariff, Rusli, & Yew (2014) was conducted at the CO2-Hydrocarbon Absorption System (CHAS) pilot plant under the Research Centre of CO2 Capture (RCCO2C), Universiti Teknologi Petronas, involving the absorption performance of the hazardous chemical named amine solvent in removing flammable gas of Carbon Dioxide (CO2) from the natural-gas stream for pressure of up to 80 bars. By having the PSI4MS, authorized personnel can upload information, update it and make the necessary follow-up. The frequency with which the data is updated depends on the required changes that need to be made at the pilot plant. In addition, other PSM elements such as PHA, Management of Change (MOC), and Pre Start-Up Safety Review (PSSR) could also be updated, thus making safety management easier in the plant process.

Another PSM element, called the contractor's involvement, was also included in this review. Previously, it was determined that some aspects, especially related to the way contractors work do not comply with the regulations and thus encouraging undesirable outcomes. According to a study revealed by Majid, Shariff, & Rusli (2015), shortcomings in the PSM contractors' management program will be organized through the implementation of this element. A Contractor Management System (CoMS) model was developed using the piping and instrumentation diagram (P&ID), and its implementation was tested at the High Gravitational Natural Gas Pilot Plant (HGNGPP) Universiti Teknologi Petronas. The pilot plant was used to study the performance of an in-line rotary separator to remove water vapor from the natural-gas stream for pressure of up to 80 bars. This pilot plant was handling flammable gas at a higher temperature. Here, a contractor played a role in replacing a corroded section of the separation columns that contain absorbents. Begin with the framework and provide a foundation for developing a CoMS prototype model to track and manage the contractor documentation and information for effective implementation in industries. The CoMS was adapted from the computer database model and was developed in the Microsoft Access environment. Interfaces were Managing Contractors, Application, Pre-Contract Screening, Site Safety Plan Checklist, Work Monitoring and Evaluation, and Accident/ Incident Report. Each interface is based on respective objectives and provides information for any company to conduct a gap analysis to determine how close the system complies with PSM requirements. The establishment of the system will assist regulatory compliance and ease the auditing process.

Another PSM element called emergency planning & response (EPR) was also defined in this review. The ERP is an important aspect of the PSM elements, which explains the minimum emergency response elements and procedures for handling emergencies or small releases. According to a study revealed by Majid, Shariff, & Loqman (2016), they aimed to present a structured and easy technique to plan and implement EPR as stipulated in the PSM system. Begin with the framework, and it provides a foundation for developing an EPR prototype model to track and manage EPR documents and information for effective implementation across industries. A model was created using Microsoft Access as the data management tool. Referring to a case study conducted using real data from a utility area of a local oil and gas refinery. Plant X in Malaysia, a model using the piping and instrumentation diagram (P&ID) was developed based on this technique and its application was tested. Plant X complies with local regulations set by the Malaysian Department of Environment (DOE) regarding the spills of hydrochloric acid (HCl). The P&ID was divided into several activity nodes according to its design as a utility area. The scenario was the release of HCl to the surrounding area and how the situation was handled and mitigated. According to the case study, Plant X did not comply with decontamination procedures and the training content of its responders and trainers. The results reflected the feasibility of this model as it helped users track and manage documents efficiently. The findings defined that this concept and structured technique was feasible and could be implemented in the CPI.

4.0 DISCUSSION

This systematic literature review aimed to reveal the effectiveness of the process safety management (PSM) system involving PSM elements in Malaysia's Chemical Process Industries (CPI). A rigorous review from three databases resulted in six articles on the implementation of the PSM system based on case studies in the country introduced by many researchers and practitioners in Malaysia.

According to previous research, contributors to accidents include technical, design, and operating errors of major types of process equipment and piping, of which 85% of accidents are caused by design and operation errors (Kidam & Hurme, 2013). The failure of the technical, design, and operation will eventually be introduced as an explosion and fire accident. To overcome this issue, Majid & Shariff (2019) demonstrated a structured and easy technique for conducting and implementing incident investigations and complying with the PSM system. It helps prompt users on the necessary actions to close the identified gaps that cause the accidents.

Adopting an upgraded PSM system has been shown to reduce the risk of chemical accidents for today's industries. Among 14 elements in the PSM system, the Process Safety Information (PSI) element is highly selected in this review. PSI is chemical, physical and toxicological information related to chemical processes and equipment. It is used to record the configuration of a process, its characteristics, its limitations, and data for process hazard analyses. PSI takes into consideration on hazards of the regulated materials typically found in safety documentation such as Safety Data Sheet (SDS). In the Malaysian situation, Aziz, Shariff, & Rusli and Aziz, Shariff, Rusli, & Yew (2014), has developed a technique based on the PSI element for document management, communication, a written programme to maintain, revise and update hazardous chemicals, equipment and technology information. Process and Instrumentation Diagram (P&ID) was used as a foundation for data management and converted into a computer database prototype known as Process Safety Information Management System (PSI4MS) to demonstrate the concept.

Meanwhile, to present a structured and easy technique for planning and implementing emergency planning & response required by PSM, the development of an EPR prototype helps to track and better EPR management. Majid, Shariff, & Loqman, (2016), aim to present a structured and easy technique for EPR planning and implementation as stipulated in the PSM system in oil and gas refinery Plant X in Malaysia. This study is supported by previous research done by Shamim et al. (2019), which introduced the EPR elemental-based Delphi technique for safer chemical processes using a mathematical model, safety performance index (SPI), based on the principle of relative ranking. It has been developed to evaluate the developed leading and lagging metrics. The established methodology was successfully applied to the case study of a major process accident, which occurred in an industrial process for the production of inorganic chemicals such as soda ash ($Na2CO3$) in Pakistan. As a result, fifteen performance metrics have been developed for the EPR element of the Process Safety Management (PSM) standard. The results provided insights into plant safety.

As we can see here, most of the implemented PSM elements found in this review used the computer database systems such as Microsoft Access and Microsoft Excel as a tool to create and manage the related safety data. This technology can help safety practitioners to collect and keep information safe and easy access compared to manual searching. In addition, the software is an ideal tool for more advanced data tracking. This statement has been supported by Early (2006). This statement was supported by Early (2006). He described the recent implementation of a database management system (DBMS) at a chemical plant and chronicles the improvements accomplished by introducing a customized system. The examples of DBMS in the chemical company such as management of change (MOC) initiation and tracking, including signoffs and email notifications, process hazard analysis (PHA) recommendation tracking with notifications and approvals, pre-startup safety review (PSSR) close-out item tracking, PSM audit corrective actions tracking, safety incident reporting and corrective action tracking, environmental incident reporting and corrective action tracking, including on-line reporting, spill release, and Community Awareness and Emergency Response (CAER) notifications, customer complaint/quality assurance actions tracking, and generic actions tracking. A current study by Lee, Cameron, & Hassall (2019), recommended today's technology deployment towards Industry 4.0 with a focus on advanced automation, robotics and enhanced human-machine connectivity. Industry 4.0 offers the opportunity to integrate and leverage current technologies and modeling approaches to improve process safety. This modeling approach systematically identifies risks that are within the tolerance criteria and if additional barrier or design changes are required, identifying independent layers of protection include critical equipment management processes and access their effectiveness to minimize consequences, generate alarm signatures that can be useful in unusual situations, identify critical operator interventions, improving procedural risk assessment and reducing the time and risk of error in the traditional risk assessment process. Thus, database systems are more useful and user-friendly tools for developing customized, configurable to fit workflows in management settings.

Therefore, effective action by industries is important to prevent recurrence and reduce the number of accidents in the workplace. Many industries have recently implemented PSM systems to reduce the severity of human and material losses caused by disasters. There are several limitations in this study. First, articles were identified using search strings from the Science Direct, Web of Science, and Scopus databases through 2020 publication. Another limitation of the review is that it was restricted to the effectiveness of the PSM in the Malaysian context. Future studies on new ideas, research and inventions from local researchers and authors are needed to improve and upgrade the framework and implementation of the PSM system in CPI in Malaysia. The invention of safety management software on the PSM system is suggested to enhance operational processes, improve risk management effectiveness, evaluate existing and available frameworks, predict accidents and consequences in the future, offer a variety of solutions and prevent undesired events. The application of safety management software is more flexible and practical to be implemented in this modern era of digitalization and automation. This software controls safety and manages risk with real-time performance monitoring to demonstrate a completely proactive and anticipative approach to operations. Improving and upgrading the PSM system framework will enhance Occupational Safety and Health (OSH) management in every work prospect. Strengthening the self-regulation practice in the workplace, promoting OSH education and research, and enhancing OSH management through technology, digitalization, and automation are eligible in improving the framework of the PSM system.

5.0 CONCLUSION

The development of this review thus demonstrated the PSM system as a mitigation measure in the elimination and reduction of hazards causing risk in the occurrence of hazardous chemical accidents in Malaysia. As a result, several authors have applied the literature of Process Safety Information (PSI) element. Meanwhile, the Process Safety Information Management System (PSI4MS) was a popular tool to implement the PSM system. PSM has achieved excellent performance in risk management, as proven over the years by current researchers. The introduction and implementation of the PSM system for CPI are necessary to reduce the risk of chemical accidents. Therefore, a systematic literature review on PSM implementation effectively manages chemical accidents in Malaysia.

REFERENCES

2018 Annual Report. (2018). *Social Security Organization (SOCSO).* Retrieved from https://www.perkeso.gov.my/images/laporan_tahunan/LAPORAN%20TAHUNAN%20_ANNUAL%20REPORT%202018.pdf

Ahmad, M. A., Ismail, N., and Othman, M. R. (2017). Dust Explosion Incidents in Malaysia for Poweder Manufacturing Industries. *International Journal of Academic Research in Business and Social Sciences, 7*(3). doi: 10.6007/IJARBSS/v7-i3/2956

Aziz, H. A., & Shariff, A. M. (2017). A Journey of Process Safety Management Program for Process Industry. *International Journal of Engineering Technology and Sciences (IJETS), 8*(1). doi:10.15282/ijets.8.2017.1.10.1085

Aziz, H. A., Shariff, A. M., & Rusli, R. (2014). Managing Process Safety Information Based on Process Safety Management Requirements. *Process Safety Progress, 33*(1), 41-48. doi:10.1002/prs.11610

Aziz, H. A., Shariff, A. M., Rusli, R., & Yew, K. H. (2014). Managing Process Chemicals, Technology and Equipment Information for Pilot Plant Based on Process Safety Management Standard. *Process Safety and Environmental Protection, 92*(5), 423-429. doi:https://doi.org/10.1016/j.psep.2014.02.011

Bakar H. T. A., Siong P.H., Yan C.K., Kidam K., Ali M.W., Hassim M.H., Kamarden H. (2017). Analysis of Main Accident Contributor According to Process Safety Management Elements Failure. *Chemical Engineering Transactions, 56,* 991-996 doi:10.3303/CET1756166

Behie, S. W., Halim, S. Z., Efaw, B., O'Connor, T. M., & Quddus, N. (2020). Guidance to improve the Effectiveness of Process Safety Management Systems in Operating Facilities. *Journal of Loss Prevention in the Process Industries, 68*, 104257. doi:10.1016/j.jlp.2020.104257

Early, W. F. (2006). Database Management Systems for Process Safety. *J Hazard Mater, 130*(1-2), 53-57. doi:10.1016/j.jhazmat.2005.07.039

Kidam, K., & Hurme, M. (2013). Method for Identifying Contributors to Chemical Process Accidents. *Process Safety and Environmental Protection, 91*(5), 367-377. doi:https://doi.org/10.1016/j.psep.2012.08.002

Kwon, H.-m. (2006). The Effectiveness of Process Safety Management (PSM) Regulation for Chemical Industry in Korea. *Journal of Loss Prevention in the Process Industries, 19*(1), 13-16. doi:10.1016/j.jlp.2005.03.009

Lee, J., Cameron, I., & Hassall, M. (2019). Improving Process Safety: What Roles for Digitalization and Industry 4.0? *Process Safety and Environmental Protection, 132*, 325-339. doi:10.1016/j.psep.2019.10.021

Majid, N. D. A., Shariff, A. M., & Rusli, R. (2015). Process Safety Management (PSM) for Managing Contractors in Process Plant. *Journal of Loss Prevention in the Process Industries, 37*, 82-90. doi:https://doi.org/10.1016/j.jlp.2015.06.014

Majid, N. D. A., Shariff, A. M., & Loqman, S. M. (2016). Ensuring Emergency Planning & Response Meet the Minimum Process Safety Management (PSM) Standards Requirements. *Journal of Loss Prevention in the Process Industries, 40*, 248-258. doi:https://doi.org/10.1016/j.jlp.2015.12.018

Majid, N. D. A., & Shariff, A. M. (2019). Incident Investigation Work-Aid Tool for Process Safety Management Compliance in Process Industries. *Process Safety Progress, 39*. doi:10.1002/prs.12113

McLeod, S. M., Payne, G. T., & Evert, R. E. (2016). Organizational Ethics Research: A Systematic Review of Methods and Analytical Techniques. *Journal of Business Ethics, 134,* 429-443. doi: 10.1007/s10551-014-2436-9

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Moher, D. (2021). The PRISMA 2020 Statement: An Updated Guideline for Reporting Systematic Reviews. *BMJ, 372*, n71. doi:10.1136/bmj.n71

Shaluf, I. M., Ahmadun, F.-R., & Said, A. M. (2003). Fire Incident at a Refinery in West Malaysia: The Causes and Lessons Learned. *Journal of Loss Prevention in the Process Industries, 16*(4), 297-303. doi:https://doi.org/10.1016/S0950-4230(03)00021-4

Shariff, A. M., & Leong, C. T. (2009). Inherent Risk Assessment—A New Concept to Evaluate Risk in Preliminary Design Stage. *Process Safety and Environmental Protection, 87*(6), 371-376. doi:https://doi.org/10.1016/j.psep.2009.08.004

Shamim, M. Y., Buang, A., Anjum, H., Khan, M. I., & Athar, M. (2019). Development and Quantitative Evaluation of Leading and Lagging Metrics of Emergency Planning and Response Element for Sustainable Process Safety Performance. *Journal of Loss Prevention in the Process Industries, 62*, 103989. doi:https://doi.org/10.1016/j.jlp.2019.103989

Shanmugam, K., & Razak, M. A. (2021). Assessment on Process Safety Management Implementation Maturity among Major Hazard Installations in Malaysia. *Process Safety and Environmental Protection*

Ying, T. P., & Ying, L. X., (2020, August 4). NST175: The Bright Sparklers Tragedy. *News Straits Times.* Retrieved from https://www.nst.com.my/news/nation/2020/08/613814/nst175-bright-sparklers-tragedy

Zhao, J., Suikkanen, J., & Wood, M. (2014). Lessons Learned for Process Safety Management in China. *Journal of Loss Prevention in the Process Industries, 29*, 170-176. doi:10.1016/j.jlp.2014.02.010