HIRARC evaluation on chemical factories in Malaysia

Cite as: AIP Conference Proceedings **2339**, 020203 (2021); https://doi.org/10.1063/5.0045231
Published Online: 03 May 2021

M. Fathullah, N. R. Nik Yusoff, Vertic Eridani Budi Darmawan, L. X. Yin, T. W. Yee, T. S. Teng, T. H. Jui, and Y. N. Fong

HIRARC Evaluation on Chemical Factories in Malaysia

M Fathullah[1,2,a)], N R Nik Yusoff[1,3], Vertic Eridani Budi Darmawan[4], L X Yin[2], T W Yee[2], T S Teng[2], T H Jui[2] and Y N Fong[2]

[1]*Green Design and Manufacture Research Group, Geopolymer & Green Technology, Centre of Excellence (CEGeoGTech), Universiti Malaysia Perlis (UniMAP), Perlis, Malaysia.*
[2]*Faculty of Mechanical Engineering Technology, Universiti Malaysia Perlis (UniMAP), Perlis, Malaysia.*
[3]*Faculty of Earth Science, Universiti Malaysia Kelantan, 17600 Jeli Campus, Kelantan, Malaysia.*
[4]*Department of Industrial Engineering, Universitas Negeri Malang, Indonesia.*

Corresponding author: [a)]fathullah@unimap.edu.my

Abstract. This paper reports on case studies of safety incidents in chemical factories in Malaysia. The processes used for identifying and evaluating both existing and potential hazards in a palm-oil work site and the way of controlling it is hazard identification, risk assessment and risk control or known as HIRARC. Many that have already done risk assessments have recorded successful changes to their working procedures, and conditions of work in establishing and taking the appropriate effective actions. An ergonomic, physical and chemical hazards is a main factor in occurred in this study that could cause damage to humans, systems and environments. The assessment was done in estate area, involving the process of oil palm harvesting and collecting operation, oil palm manuring, and oil palm field upkeep and maintenance. The overall methodologies in this study consist of fishbone concept, HIRARC and PARETO analysis towards the working procedures at loading ramp station in palm factory. At the end of this paper, a list of recommendations is made to ensure the risk assessed can be minimzed in future.

INTRODUCTION

Manufacturing industries today is heading towards advances in technology, process as well as its quality[1-3]. These situation has led to more awareness on safety and health, which is now significant. A safe work environment and work habits are crucial to avert accidents and ensure optimal work performance. However, accidents can occur in all situations. Therefore, a risk assessment at work is essential to identify possible risks. Organizations conducting risk assessments in the workplace have noticed many changes in business practices. By cutting down the risk and danger, a person or company can reduce the chance of an accident.

A risk assessment can be defined as a detailed examination of the material or articles related with or used by a potentially harmful work function. Milczarek and Kosk-Bienko [4] pointed out that risks can be categorized into physical, psychosocial, chemical, and biological hazards. Risk is explained as the product of the probability of a detrimental event and the severity of the event [5]. In literature of Wijeratne et al. [6] describes that risk is the potential for hazards. Risk is not only risky; it is also a precarious practice that can be evaluated [7]. Nonetheless, a combination of damage and the likelihood of damage occurring [8] can be defined by risk.

The law requires a systematic documented process to ensure reliable results and complete analysis. A person who has conducted a risk assessment in the workplace, has reported positive changes in business practices, behaviors, and working conditions and has taken and implemented necessary corrective measures. Therefore, the risk assessment process must be continuous and cannot be considered a one-time job..

Proceedings of Green Design and Manufacture 2020
AIP Conf. Proc. 2339, 020203-1–020203-9; https://doi.org/10.1063/5.0045231
Published by AIP Publishing. 978-0-7354-4091-3/$30.00

ABOUT THE CASE STUDIES

This paper reports on 5 case studies related to hazard and safety issues and elucidates the potential source of hazards. At the end of this result, a Hazard Identification , Risk Assessment and Risk Control (HIRARC) analysis was developed and solutions for each of the hazards studied were proposed.

Case 1

In the year 2015, an Ammonia gas cylinder was reported having explosions at an ice making industry in Kuala Lumpur. The incident occurred when a worker was transferring the ammonia gas from the gas cylinder to the receiving tank. The full gas cylinders in chemical plant was placed in reclining position and for the empty cylinder was in upright position. The cylinders are majority stored in the chemical plant over 20 years. This incident had killed on worker due to the impact of the the explosion while another worker get had minor injuries [9].

Case 2

A worker in charge of the chemical blending operation was removing his impervious gloves and replaced them with cotton gloves. The replacement was made as the worker thought that the cotton gloves would provide sufficient protection. The worker started blending after he use a hand pump to transfer the corrosive substance from storage. After carrying the operation, the worker experienced pain on his fingers. He was then brought to the hospital and warded[10].

Case 3

A moving contractor transported a 20-foot-long container to a factory for loading chemical barrels. When the manager did not communicate with the driver through the intercom, he sent a colleague to find him. It was found that the mover driver was unconscious and later stuck in between the cab and the mover stopped at the factory cabin door. The mover rushed forward, keeping the cabin door close to the open leaves of the factory's main entrance. The scene of the accident was: the driver was trapped between the side of the cab and the door of the cab, and this door was initially fully opened and was located on the roadside. The hinge was cut off and the door was moved to this position to indulge the driver [10].

Case 4

A tragic accident occurred at a process plant area. A worker was checking on a site in an erected scaffold under the heat exchanger. When the worker was returning from the location, the he accidentally fell into a deep pit of 1.2 m depth of hot pit condensor. The worker was declared dead due to severe injuries and burns experienced a few days after taken into the hospital [11].

Case 5

The final case study is about a worker who is doing a task of dismantling a metal scaffold inside a reactor at chemical industry. After completing the task, the worker was getting ready to exit through the overhead reactor manhole from the base of the reactor. While, the manhole was located at 14m high from the base of reactor. Due to this height, the worker should have enough effort to grip the rope and climb up to exit the manhole. However, the worker who conducted this task has not attach himself tight enough to the provided fall arrestor. This caused an accident of fall from height was happened when the worker was climbing up the vertical rope ladder. The worker was fell and landed at the base of reactor. At the same time, the worker died on the way to the hospital even though he was immediately rescued [12].

METHODOLOGY

The methodology of this paper starts with analyzing the root cause using fishbone diagram in every case study. In this method, hazard was identified using HIRARC analysis and Pareto chart to address and analyze the hazard having highest risk that need to be solve immediately. Fishbone diagram was then used in this paper to identify the root cause for each case study. The process of breaking down each cause from this tool, is analyzed until the root causes to the problem is identified [12]. The methodology of this HIRARC analysis is based on the guideline for Hazard Identification, Risk Assessment and Risk Control (HIRARC) from the Department of Occupation Safety and Health (2008) [13]. Based on the guideline, HIRARC analysis is run at 4 different steps which are classifying work activities, identifying hazard, conducting risk assessment and decide if risk is tolerable and apply control measures. In risk assessment, likelihood and severity was rated from 1 to 5 depending on the incident, the value for the rating are shown in Table 1 and Table 2. The risk was then calculated using according to the risk matrix as shown in Equation 1 and Fig. 1. A Pareto Chart was then developed to analyse and observe the priority of hazards need to be tackled.

$$\text{Relative Risk} = \text{Likelihood} \times \text{Severity} \tag{1}$$

Likelihood (L)	Severity (S)				
	1	**2**	**3**	**4**	**5**
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5

Low Risk Medium Risk High Risk

FIGURE 1: The risk matrix.

TABLE 1: Likelihood rating.

Likelihood	**Example**	Rating
Most Likely	The most likely result of the hazard/ event being realized	5
Possible	Has a good chance of occurring and is not unusual	4
Conceivable	Might be occur sometime in future	3
Remote	Has not been known to occur after many years	2
Inconceivable	Is practically impossible and has never occurred	1

TABLE 2: Severity rating.

Severity	**Example**	**Rating**
Catastrophic	Numerous fatalities, irrecoverable damage and productivity	5
Fatal	Approximately one single fatality major property damage if hazard is realized	4
Serious	Non-fatal injury, permanent disability	3
Minor	Disabling but not permanent injury	2
Negligible	Minor abrasions, bruises, cuts, first aid type injury	1

RESULTS AND DISCUSSIONS

Case 1: Hazard due to explosion

There are 5 major factors the explosion occurred due to the worker was conducting the work of filling the ammonia gas. As can be seen in Fig.2, the root causes that contribute to the hazard are the workers are not followed the standard operating procedure (SOP) stated. Besides, the improper method of handling ammonia gas with insufficient training and safety procedure provided also lead to the incident to happen. In addition, filling ammonia gas without using weighing machine with clear calibration shown result in overfilled which causes explosion to occur. The ammonia gas cylinder is stored outdoor direct under the sun also one of the root cause that lead to the explosion. The ammonia gas cylinders using and storing for more than 20 years become the major factor contribute to the hazard.

The hazard can be solved by carrying periodic inspections and testing of the ammonia gas cylinder followed by the codes or standards and also conducting a maintenance and preventative schedule for ammonia gas cylinder. Proper training and information on safe procedure and method of handling ammonia gas cylinders followed by close supervision by supervisors. Furthermore, the gas cylinder should be stored and protected away from the hot sun. The full and empty ammonia gas cylinder need to be stored separately and marked with different signs to prevent confusion. Besides, it should be arranged in upright position and held firmly in a securely fenced area to prevent falling, overturning and knocked over.

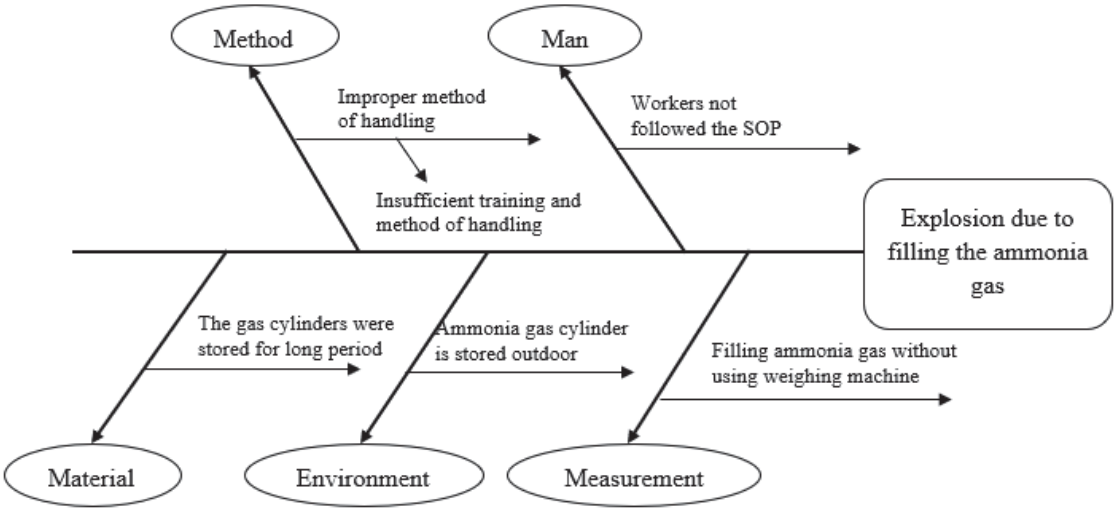

FIGURE 2. Fishbone structure for explosion

Case 2: Hazard due to burning

The major factors that contribute to this incident are from men, material and management. The worker exchanges his impervious gloves into cotton gloves while blending the chemical, this shows that the worker does not have sufficient knowledge about proper handling of the corrosive chemical. Besides, only verbal instructions were given by the management, this causes the worker to neglect the importance of safe work procedures.

There are few recommendations for this case study as shown in Fig.3, in order to avoid similar injury happen again. First and foremost, the management must organize sufficient training in hazard communication and provide safety briefings so that every workers are fully aware of the risks. Management should provide supervision and documentation of the safe work procedures for all workers when there are handling the corrosive chemicals. The workers must also fully committed in the safe work procedures such as using the correct equipment and protection while handling corrosive chemical and reach for help immediately if any injury happed during work.

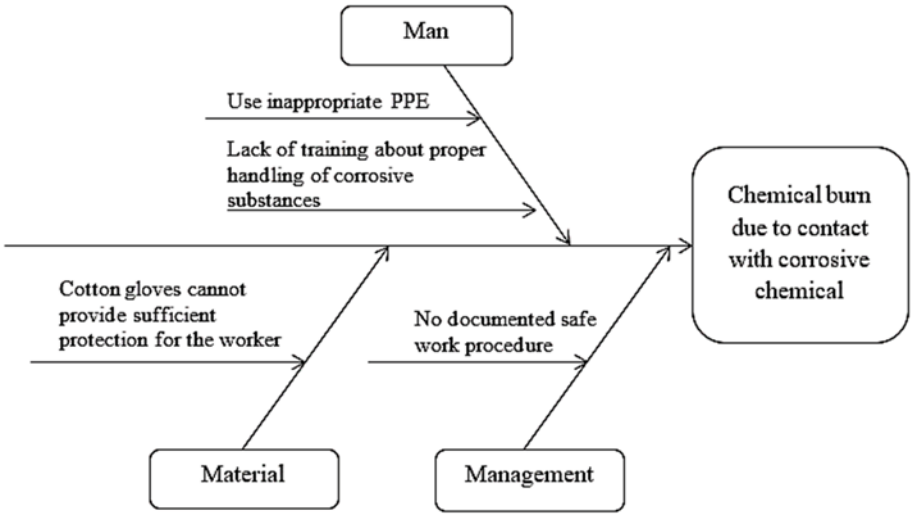

FIGURE 3. Fishbone structure for chemical burn

Case 3: Hazard due to caught in between objects

Causal analysis is done by this case with loss assessment of one death; type of contact: trapped between the mover compartment and the door. Figure 4 shows that the direct cause of this case is insufficient gap between mover and main brake while the basic cause is the mover moves during loading process. Failures of the safety and health management system was: hazard identification, risk assessment and risk control; operating procedures and safe working specifications. Fishbone diagram in Figure 4.3 is figure out the cause and effect of the incident of caught in/between objects.

Suggestions and learning points:

1. Specify and clearly delineate appropriate work areas for safe handling.
2. During the loading/unloading process, the mover should be disengaged from the container.
3. Wheel clamp must be installed on the mover to prevent accidental movement during loading/ unloading.

(1) On the slope; (2) Close to obstacles; (3) Front wheel steering obstacles; and (4) The mover and trailer/container are connected during the loading/unloading operation.

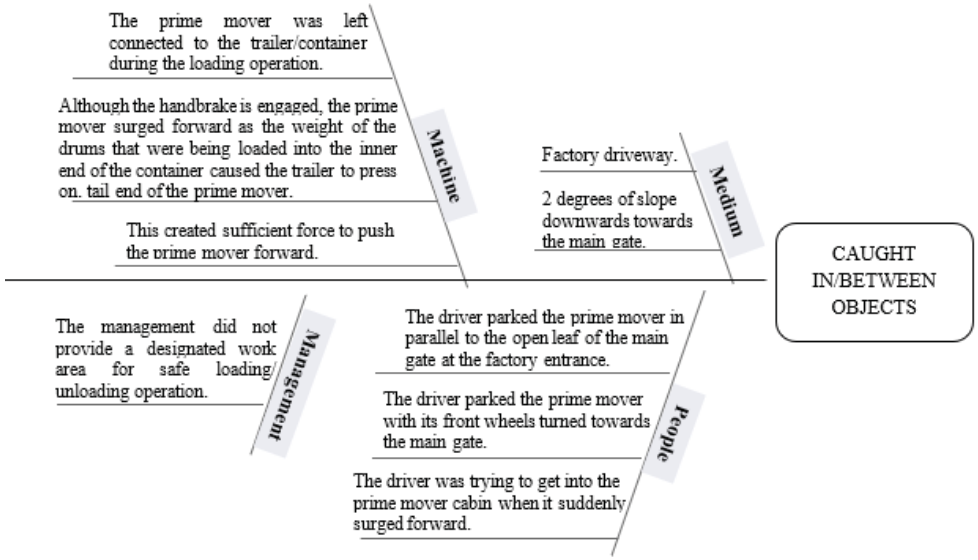

FIGURE 4. Fishbone structure for falling object

Case 4: Hazard due to burning: hot steam fall

The possible causes of the hazard are listed in Fig. 5, in term of environment, man, material, and management. The solution are proposed for purpose of minimize the effect of each causes. In order to prevent occurrence of the scald burn accident, the top management of the company should install permanent cover or proper barricade for the deep pit and always ensure the cover or barricade are in good condition and function well. Moreover, must provide a walkway which safe for peoples' access at the site, and a warning sign must install at the pit's location to warning worker. Besides, the top management of the company are recommend to provide safety and health program or training for employees to improve safety of workplace and increase safety awareness of employees. Also, a safe work procedure during site check may help in accident prevention.

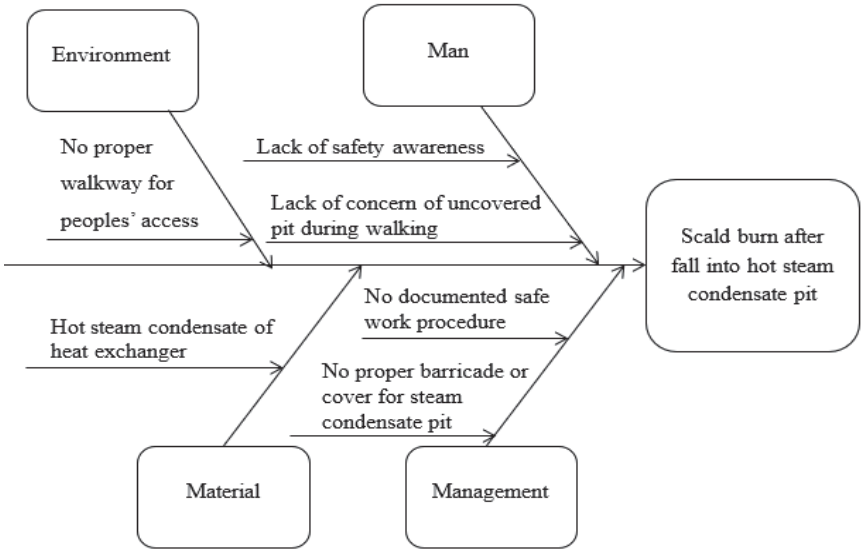

FIGURE 5. Fishbone structure for repetitive movement hazard

Case 5: Hazard due to Smoke Exposure

Figure 6 shows that the reasons of causing the accident of fall from height to happen at the workplace. Factors of man (worker), material at workplace, method used when doing the task, and management by the company will cause the hazard to occur. In order to reduce the incident from happening, the worker must have enough rest, because physical emotion will influence the performance of work. Meanwhile, to prevent the fatal to happen, safe work procedure is important for every worker in order to complete the work in safe situation. Some incident will also happened due to the chemical reaction between the chemical substances. Therefore, worker must always be careful with the belonging on the body

Besides that, the top management of the company was responsible on scheduling the worker to attend the safety training from time to time and always supervision them to ensure that each of the worker attached their body harness to the provided life line before climbing up the rope ladder. Equipment that used in workplace also has to do the maintenance to ensure the equipment is functionable. The recommendations control are ensure the workers are welled rested and medically fit for strenuous work activities such as using the rope ladder. Emphasize the need to properly secure the body harness before using the rope ladder during worker training and suggest to use fixed ladder rather than of a rope ladder.

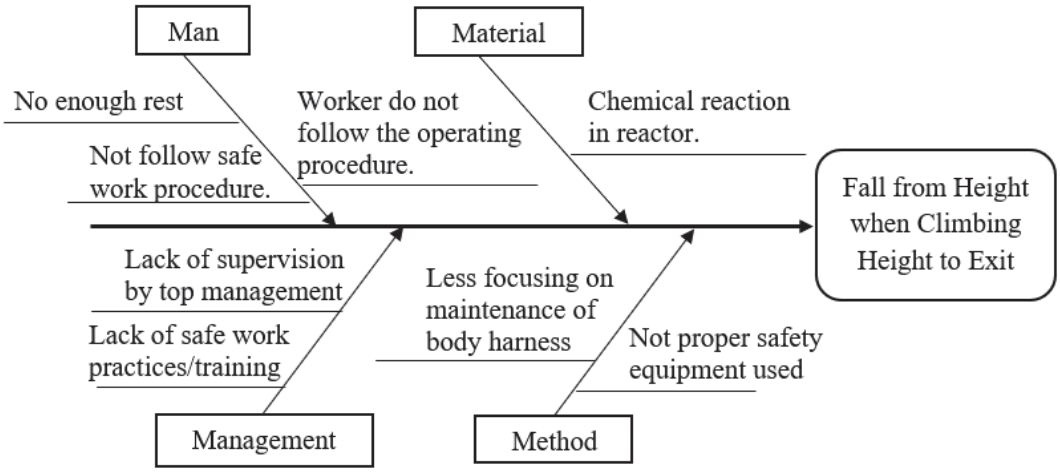

FIGURE 6. Fishbone structure for smoke/ unhealthy air hazard

Figure 7 shows a bar chart/ Pareto Chart listing the priority rank order of the safety incidents The chart is plotted based on the cumulative percentage of the risk scor as calculated based on Table 3. The highest risk score is 20 which related to the activity of parking the mover at factory with inclined 2° downwards that cause accident of caught in/between objects. Next, the second high risk score is 16 which are related to the activities of transferring and blending the corrosive chemical, doing site checking on an erected scaffold at a heat exchanger and also climbing up to exit reactor from height. The risk score is followed by 15 which related to filling the ammonia gas. It was observed that activities of dismantling the metal scaffold inside the reactor and during loading process, mover near to the trailer/ container has the lower risk score of 9 and 8, respectively. In conclude, the 80% contribution line somewhere in between "working at height" and "overfilled of the ammonia gas". From the Pareto chart, 1st until 4th hazard having the biggest weight of risk score. Therefore, the activity with high risk score needs to be set as the most priority to solve.

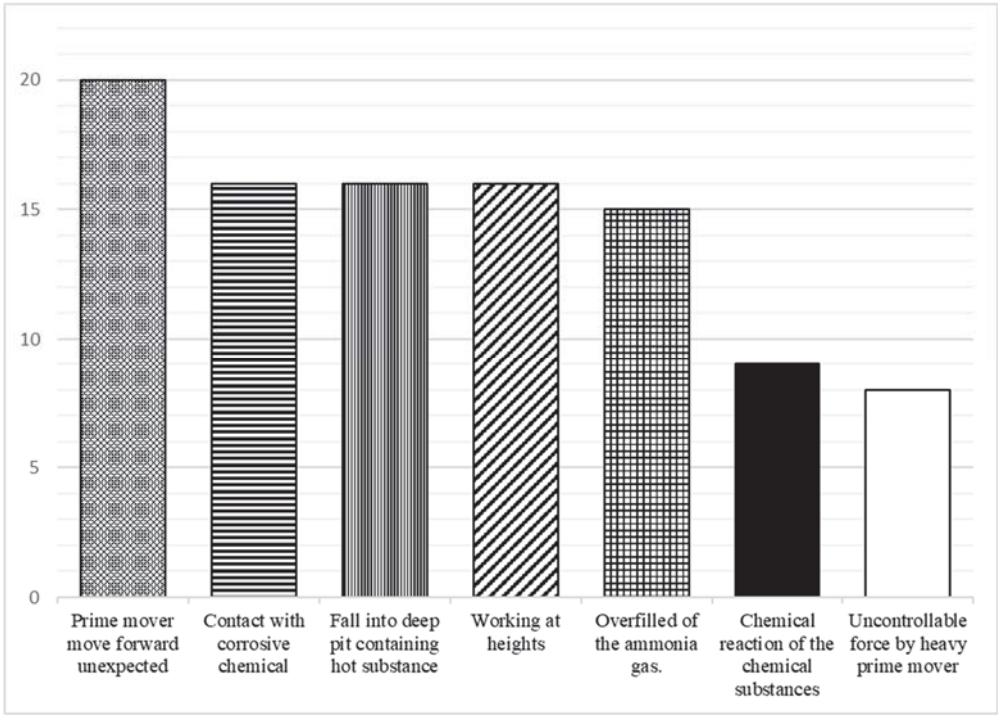

FIGURE 7: Risk Priority from Pareto Analysis

TABLE 3. HIRARC Analysis on case studies.

Hazard identification				Risk analysis				Risk Control	
No	Activity	Hazard	Cause/ Effects	Existing Risk Control	Likelihood	Severity	Risk	Recommende Control Measures	PIC and Due Date
1.	Filling the ammonia gas	Overfilled of the ammonia gas	Explosi on and get burned	Given proper training and written guidance	3	5	15 (High)	Provide safety procedure and method of handling ammonia gas cylinders.	NA
2.	Transfer and blending the corrosive chemical	Contact with corrosive chemical	Chemi cal burn	Given proper training and use appropriate PPE	4	4	16 (High)	-Provide sufficient training and use appropriate PPE. -Provide sufficient supervision to workers handling corrosive substances.	NA
3.	During the loading process, the mover remains connected to the trailer/cont ainer	Sufficient force generated during loading may push the mover forward	Caught in/ betwee n object	No action is taken	4	2	8 (mediu m)	During the loading/unloading process, the mover should be disconnected from the trailer/container	NA
4.	The mover/trail er/containe r is parked inclined 2 degrees downwards towards the main door	mover or trailer may move forward unexpected	mover hit the worker	Handbrake is engaged.	4	5	20 (high)	-Specify and clearly delineate appropriate work areas for safe handling. -Position the wheel clamp under the trailer	NA
5.	Do site check on an erected scaffold at a heat exchanger	Fall into deep pit containing hot steam condensate	Scald burn of human body	No action is taken	4	4	16 (High)	-Install permanent cover for the deep pit and always ensure the cover are in good condition. -Put warning sign at the pit's location to warning worker. Prepare a walkway for worker to pass through safely.	NA

CONCLUSION

Hazard Identification, Risk Assessment and Risk Control (HIRARC) is the useful tool that conducted at the workplace to determine the activity carried out and figure out the type of hazard and risk that might cause an accident

to occur. The analysis and suggestion outlined in this report is hoped can be a guideline for industries as a reference so that preventive actions can be employed to avoid unwanted accident from occurring again in future.

REFERENCES

1. P. Y. Fauziah, M. Fathullah, M. M. A. Abdullah, Meor Ahmad Faris, Faheem Tahir, Z. Shayfull, S. M. Nasir, M. Shazzuan, and A. Z. W. Wazien. AIP Conference Proceedings, 2030, 1,020067 (2018).
2. N. Kamilah, M. Fathullah,M. M. A. Abdullah, M. A. Faris, F. Tahir, Z. Shayfull, A.Z. W. Wazien, AIP Conference Proceedings, 2030, 1, 020065 (2018)
3. M. Faiz, Z. Shayfull, S. M. Nasir, M. Fathullah, and M. M. Rashidi, AIP Conference Proceedings, 1885, 1, 020071 (2017).
4. E. Ilbahar, K. Ali, C. Selcuk and K. Cengiz, Safety Science 103, 124-136 (2018).
5. J. M. Stellman, “Encyclopaedia of occupational health and safety” (International Labour Organization, 1998).
6. G. Muhammet and M. Fatih, J. Clean. Prod 196, 653-664 (2018)
7. C. D. Reese, “Occupational health and safety management: a practical approach”. (CRC Press, 2018).
8. L.Veruscka, L. Fontana and I. Iavicoli. La Medicina del lavoro 110, no. 5 (2018): 327-338.
9. Information on https://www.slideshare.net/hamidisaidin/case-study-chemical-accident.
10. Goyena and A. Fallis, J. Chem. Inf. Model., 53, 9, 1689–1699 (2019).
11. L. Hambleton, "Treasure chest of six sigma growth methods, tools, and best practices," (Crawfordsville, Indiana, Pearson Education, Inc, 2007.
12. M. Coccia, Journal of Social and Administrative Sciences, 4, 291-303 (2018).
13. Guidelines for Hazard Identification, Risk Assessment and Risk Control (HIRARC), Malaysia: Department of Occupational Safety and Health, Ministry of Human Resources, 2008.