Journal of Engineering Science 14(1), 2023, 53-63
DOI: https://doi.org/10.3329/jes.v14i1.67635

JES
an international Journal

ACCIDENTS IN CHEMICAL & PROCESS INDUSTRIES OF BANGLADESH: AWARENESS AMONG PEOPLE WORKING IN CHEMICAL & PROCESS PLANTS

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Received: 25 August 2022 Accepted: 03 June 2023

ABSTRACT

Chemical usage has steadily expanded in tandem with economic expansion, resulting in an increase in chemical accidents. Chemical incidents endanger lives and can cause a slew of health issues for those who live near chemical factories. The purpose of this study was to evaluate the knowledge of chemical accidents in chemical sector and awareness about the risk they pose among those working in chemical facilities and process plants. The research was conducted through survey which was composed of questionnaire regarding chemical safety and chemical accident in different chemical sectors participated by 120 people working in different chemical plants. Although the process safety has not mentioned in any kind of safety rules and regulations or acts the employee should have received the safety training to mitigate hazardous situation. The study shows that there was a lack of awareness and negligence of using PPE in most of the employees. A large number of respondents were doubtful of their plants following safety rules and regulations and also there was a negligence of following rules and regulations among the employees. Though there is eagerness to take safety training but most of the plants didn't provide proper training to their employees.

Keywords: *Accident, Awareness, Chemical hazard, Chemical plants, Survey.*

1. INTRODUCTION

More and more hazardous compounds are being processed by the chemical plants today in densely populated regions. The dangers associated with storing, transporting, processing, and distributing these potentially harmful substances are getting increasingly intricate. It is possible that process aberrations in the CPI will lead to failure if they are not adequately controlled because of the interplay between these elements as well as human factors and organizational and management concerns (Papazoglou et al., 1992, Khan and Abbasi, 1998). Figure 1 shows that while some process failures may be recovered from, others grow into small or significant accidents and losses. Process plants are generally equipped with a complete process control system in order to ensure smooth operation and to prevent accidents, which helps keep the plant's economy at desired levels. In spite of all of these precautions, accidents still occur.

Enhanced chemical event surveillance has been acknowledged by the worldwide community through the World Health Assembly. There are three basic reasons why this is necessary. First and foremost, chemical mishaps will continue to be a problem due to the industry's fast expansion and globalization. As a second consideration, chemical events can have ramifications that extend much beyond their initial site and even span international boundaries. Cyanide was spilled from a gold mine in north-west Romania into the local river system, causing fish fatalities throughout Romania, Bulgaria, and the Czech Republic (Olowokure et al., 2005). Another example is the worldwide distribution of dialysis filters contaminated with perfluoroisobutylene. Before the issue was uncovered, people died in Colombia, Croatia, Germany, Italy, Spain, and the United States (Olowokure et al., 2005). For one thing, the use of chemicals for terrorist objectives has sparked anxiety because of incidents like Tokyo's subway attack and indications that ricin is being prepared to be used (Masuda et al., 1995).

Bangladesh's economy is mostly based on agriculture. Bangladesh's government has taken attempts to encourage industry in the country. A growing number of chemical process industries are emerging as a result. To a great extent, Bangladesh's economy is dependent on these chemical process sectors (Sarker, 2005). However, there have been some notable accidents in several of these plants. Because the country is heavily populated, any type of chemical tragedy might pose a significant risk to the inhabitants who live nearby. Tables 1 and 2 provide examples of recent accidents in the chemical process sectors, as well as some essential facts. Table 1 depicts the worldwide accidental situation, whereas Table 2 depicts the Bangladesh scenario.

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ISSN 2075-4914 (print); ISSN 2706-6835 (online)

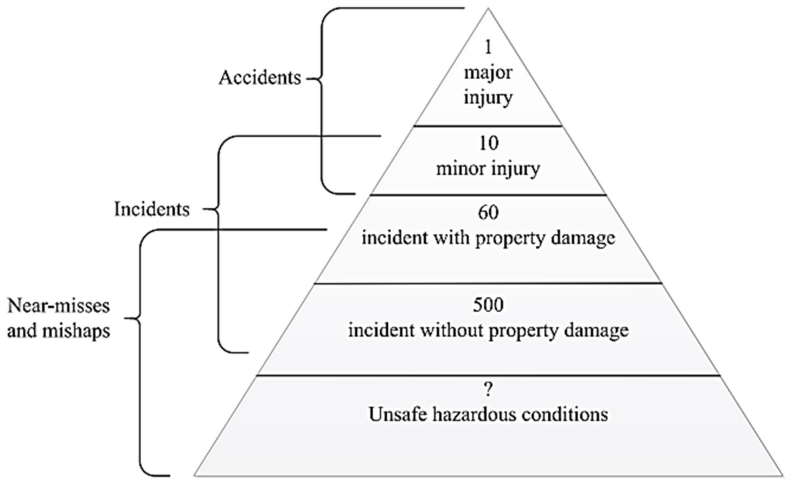


Figure 1: Safety pyramid (adapted from Al-Shanini et al., 2014).

Hazardous chemicals are monitored and handled by suitable laws and regulations in many countries in order to prevent chemical incidents (Han and Park, 2018). Although these regulations attempt to protect residents from hazardous chemical exposure, they are often regarded as insufficient to safeguard citizens' health and safety from hazardous chemical exposure. Citizens, in particular, do not get reliable information and countermeasures when a chemical disaster happens, which can easily lead to societal discontent. Furthermore, businesses have obligations regarding the provision and use of personal protective equipment (PPE) at work in order to safeguard the health and safety of workers (Yoon et al., 2004). To safeguard residents' health and safety against chemical mishaps, the government or local government may need to offer PPE if individuals request it. This study intends to evaluate people's knowledge of hazardous chemicals while working in chemical plants; also, we assess the awareness of workers who do not directly handle chemicals in chemical plants, such as office workers, drivers, and security personnel. These concerns are investigated using a questionnaire that has four items: knowledge of chemical danger, awareness and execution of safety laws and regulations, preparation for countermeasures in chemical incidents, and awareness of the usage of PPE.

Table 1: The global accident scenario in chemical process industry.

Year of accident	Location of accident	Type of Industry	Accident release	Possible causes	Consequences	Reference
1984	Bhopal, India	Chemical Industry	Methyl iso-cyanate (MIC)	Failure of several safety systems, inadequate emergency planning and community awareness, Freon system was shut down, Scrubber was turned off.	Over 2000 civilians dead and 20000 injuries	(Chouhan, 2005)
1988	Piper Alpha, North Sea	Oil and Gas platform	Gas and oil	Due to the continuous maintenance work on a pump and related valves, leakage occurred in the condensate line.	165 deaths, 30 missing, 61 survivors, total loss £1.7 billion	(Drysdale and Sylvester-Evans, 1998)

Year of accident	Location of accident	Type of Industry	Accident release	Possible causes	Consequences	Reference
2005	BP Texas City	Oil and Gas Industry	Hydrocarbon vapor cloud	Miscommunication and instrument malfunctioned, found numerous safety issues, safety regulation violated, incompetent supervision, defective alarms, safety documentation missing	15 deaths, over 180 injuries, total loss US$21 million	(Holmstrom et al., 2006)
2010	Deepwater Horizon	Oil and Gas platform	Gas component of the slushy material	Safety documents, procedure regarding emergency situation were missing, failure of shear ram to plug the well	11 crewmen dead, estimated total loss US$200 million	(Sy and Tinker, 2013)
2010	Connecticut power plant	Power plant	Natural Gas	371 safety regulations violated in the construction.	6 deaths, 50 injuries, total loss US$16.6 million	(Puskar, 2010)
2013	West Fertilizer Company	Fertilizer Industry	Ammonium nitrate	Fire was set intentionally, failure of storing the chemicals safely, regulation regarding hazardous materials handling and storing was insufficient	15 deaths, 160 injuries, 150 buildings destroyed	(Babrauskas, 2017)
2019	Philadelphia Energy Solutions refinery	Oil Industry	Vapor cloud of hydrofluoric acid	Leakage in hydrofluoric acid pipeline due to ruptured elbow	No deaths, 5 injuries	(Melnikova et al., 2020)

Table 2: The accident scenario of Bangladesh in chemical process industries.

Year of accident	Location of accident	Type of Industry	Accident release	Possible causes	Consequences	Reference
1974	UFFL, Ghorashal	Fertilizer Industry	NH_3	Faulty facility layout and design of control room	2 deaths, 17 injuries	(Tadele, 2021)
1991	UFFL, Ghorashal	Fertilizer Industry	CO_2/NH_3	Inadequate safety reviews, hazard analysis not performed, safety drill and procedures were not followed, control room power system failed	11 deaths, 50 injuries, total loss US$60 million	(Rahman et al., 2014)
2005	Magurchhara	Gas Industry	Natural gas	Blowout was uncontrollable and ignited and the rig was	Environmental damage, total loss Tk	(Khan and Nasir, 2014)

Year of accident	Location of accident	Type of Industry	Accident release	Possible causes	Consequences	Reference
				sank and destroyed.	9000 crore	
2005	Tangratilla	Gas Industry	Natural gas	Because of a uncontrolled mud suddenly lost in the well, gas flew with a very high speed.	Environmental damage	(Khan and Nasir, 2014)
2006	KTS factory	Textile Industry	Fire	Safety measures were inadequate	54 deaths, many more hospitalized	(Ahmed and Hossain, 2009)
2011	Global Heavy Chemicals, Narayongonj	Chemical Industry	Cl_2	Failure of pipe occurred because of rust	Toxic gas exposure 100	(Syeda, 2020)
2016	DAP-1, Anawara, Chittagong	Fertilizer Industry	NH_3	Failure of pressure relief system and mechanical integrity, process hazard analysis not performed	250 sick, 50 hospitalized, environmental damage	(Syeda, 2020)
2016	Tampaco Foils Ltd	Tobacco packaging company	Gas leaks	Unsafe chemical storage, Lack of monitoring system, inadequate emergency response planning	35 deaths, 100 hospitalized	(Wahed, 2018)

2. RESEARCH METHODOLOGY

A systemic review has been performed to analyze the impact chemical accidents on human lives. The summary of the findings is shown in Table 1 and Table 2. It was observed that chemical incidents that lead to human exposure present an important public health challenge both nationally and globally. The findings motivated the authors to perform an assessment survey to investigate the awareness of people who are working in different chemical and process industries. The survey was conducted through questionnaire which was composed of four sections namely the probability of chemical accident in different chemical industry and process plants such as oil industry, gas industry, fertilizer industry and others (Murphy 2017), types of accidents and their probability of occurrence, potential for fatality, potential for economic losses, awareness regarding chemical accidents and how to mitigate the losses in the occurrence of chemical accidents, awareness regarding the safety rules and regulation and usefulness of PPE. The research was conducted through data collection which was done through online data collection by creating google form and sent it to officers and engineers of different chemical and process industries.

A total 500 participants have been reached but 120 people responded from different chemical and process plants. The decision to survey 500 people in this study can be justified based on several factors, including statistical considerations, feasibility, and resource constraints. A good sample size is between 1% and 10% of the population, with a maximum of 1000 people. If there are 5,000 people in a given area, then 10% of that number is 500. If there were 200,000 people in a city, then 10% of that number, or 20,000. Since this is greater than 1000, the upper limit, in this case, is 1000 (VanVoorhisand and Morgan, 2007). So, the number of participants can easily fall in the acceptable range. Figure 2 shows the percentage of different chemical sectors where the participants are working.

In this case studies, 66 participants (55%) are working at gas sector, 26 participants (22%) are working at fertilizer sector, 13 participants (11%) are working at oil sector, 2 participants (1%) are working at chemical industry sector and the remaining 13 participants (11%) are working at other chemical sectors. Among the participants, 80 participants (66.67%) are engineers and 40 participants (33.33%) are managers in profession (Figure 3). Engineers are responsible for plant's operation, control, production, safety and emergency handling whereas the officers are responsible for supply chain, customer service, financial and human resource sections who do not directly handle chemicals in chemical or process plants.

All the participants are working in different chemical sectors and know the probability of chemical accident, potential for losses and the deficit of safety rules and regulations in their plants. So, we asked the participants a series of questions regarding the chemical accidents and how they cope with the previously occurred chemical accidents and preventive measures they take to mitigate further accidental situation.

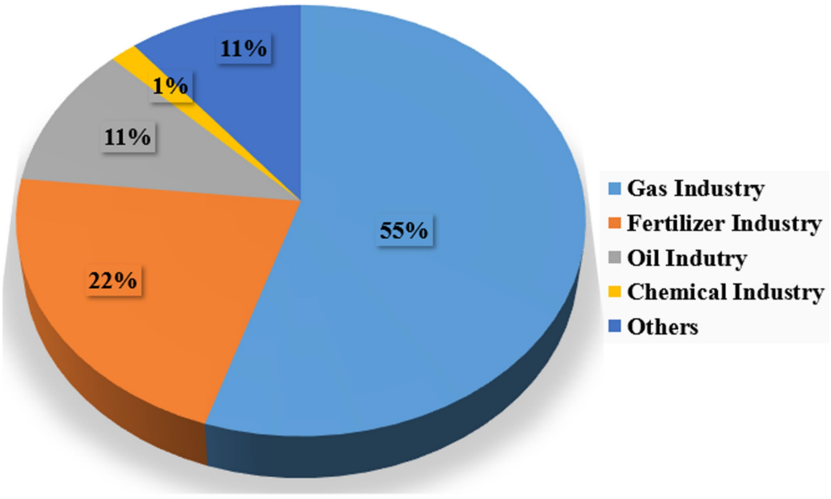


Figure 2: Participants' percentage in different chemical and process industries.

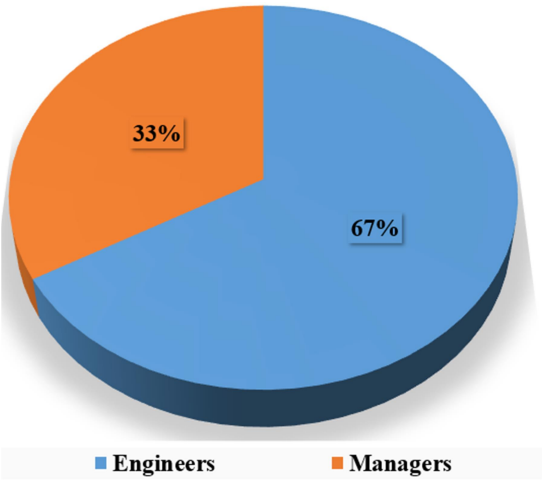


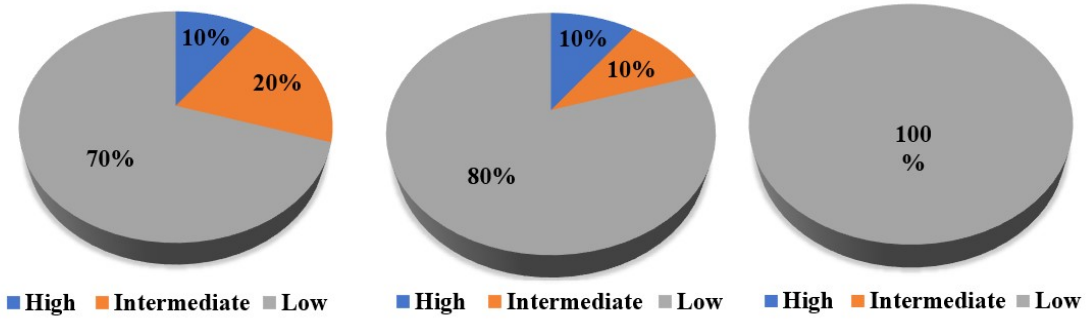
Figure 3: Scenario of participants' profession.

3. RESULTS

3. 1 Possibility different types of chemical accidents

To point out the different types of chemical accidents occurrence in different chemical industries, participants were asked to fill out the questionnaire. Chemical accidents encompass a broader range of incidents involving hazardous chemicals, which can include fires, explosions, leaks, spills, or other unplanned events associated with the handling, storage, transportation, or processing of chemicals (Murphy 2017). For answering the question "Do you think there is a possibility of fire accident in your plant?", in response to those 12 (10%) participants answer was high, 24 (20%) participants answer was Intermediate and the remaining 84 (70%) participants answer was Low. For the question "Do you think there is a possibility of explosion in your plant?", response was 12 (10%) participants answer was high, 12 (10%) participants answer was Intermediate and the remaining 96 (80%) participants answer was Low. And for the question "Do you think there is a possibility of Toxic release in your plant?", response was 120 (100%) participants answered low. This response was shown in Figure 4. High,

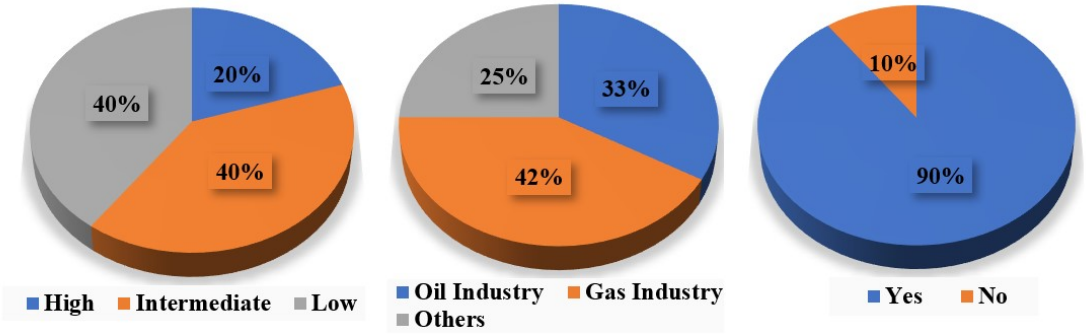
intermediate and low possibility were based on the special distribution and number of chemical accidents and factories for a particular area (Heo et al., 2018).



(a) **(b)** **(c)**

Figure 4: Possibility of different types of chemical accidents (a) fire, (b) explosion, (c) toxic release.

Moreover, in case of accident 20% answered that the potential for fatality was high in their plant, 40% answer was intermediate and the remaining was low. Also, the economic losses were enormous according to most of the participants. The participants also mentioned the probability of occurrence of chemical accident in their plant. According to the survey, Gas Industry and Oil Industry had the higher probability of occurrence of chemical accidents than the other chemical Industries and 90% these plants had taken proper preventive measures to mitigate losses in case of chemical accidents while 10% did otherwise. This response was shown in Figure 5. Here, the potential for fatality was based on the technique which was followed for Figure 4.



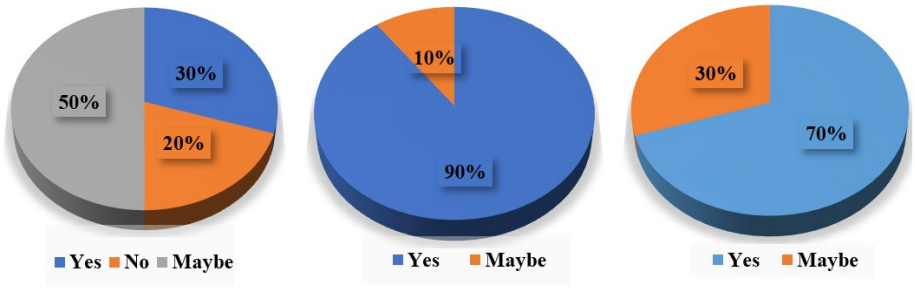
(a) **(b)** **(c)**

Figure 5: Chemical accidents occurrence, effects and countermeasures (a) Potential for fatality (b) Probability of occurrence (c) Preventive measures taken.

3.2 Awareness and implementation of safety rules and regulations

In the Labor Act, 2013 occupational safety for industrial facilities is addressed and a safety manual is also provided for plants to follow (Barua and Ansary, 2017). But the process safety has not mentioned in any kind of safety rules and regulations or acts. In this regard for inspecting the awareness of chemical safety rules and regulations among the participants and to determine whether their plant complied with all the safety rules and regulations, a questionnaire survey was conducted Figure 6.

A huge number of respondents (50%) didn't even know whether their plants follow all the chemical safety rules and regulations or not. 20% of participants responded that their plant didn't follow the chemical safety rules and regulations and the remaining 30% responded positively that their plants follow chemical safety rules and regulations. 90% participants answered that they were aware of the chemical safety rules and regulations and remaining 10% were confused about the rules and regulations. To response to the question "Does your plant have safeguard for countermeasures against chemical accidents?", 30% respondents had confusion about it and answered "Maybe", and 70% answered in positive way.

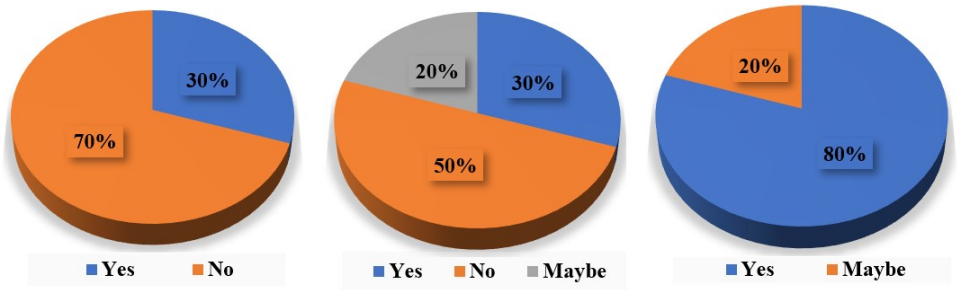


(a) **(b)** **(c)**

Figure 6: Awareness and implementation of safety rules and regulations (a) Plants followed safety rules and regulations, (b) Awareness of chemical safety rules and regulations of the employees, (c) Plants have safeguard.

3.3 Training for countermeasures against chemical accidents

According to Occupational Safety and Health Administration (OSHA) standard, before the engagement of any potential hazardous works, the employee should have received the safety training and the employers must provide safety training to all the workers who face hazards on the job (Miller et al., 2000). All the public and private sectors chemical industries should organize the safety training to help the employees to recognize plant safety hazards and occupational safety hazards and to take corrective measures accordingly. It also ensures a safe working environment. In this regard, the participants were asked a series of questions to find out the status of their chemical safety training (Figure 7).



(a) **(b)** **(c)**

Figure 7: Training for countermeasures against chemical accidents (a) plant provide safety training to all employees, (b) had enough training for preventing chemical accidents (c) needed more chemical safety training.

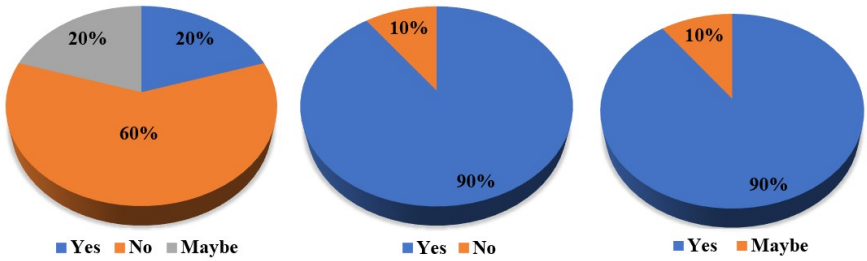
For answering the question, “Do your plant provide safety training to all the employees?”, 70% participants answered negatively and the remaining answered positively which suggesting that the majority of plants did not recognize the importance of safety training. Moreover, to answer the question, “Do you have enough training in your plant for countermeasures against chemical accidents?”, 50% respondents answer was “No”, 20% said “Maybe” and only 30% respondents answered “Yes”. Most of the respondents (80%) agreed that they needed more training for countermeasures against chemical accidents and 20% were confused.

3. 4 Awareness of using PPE

Personal Protective Equipment (PPE) is a safety equipment which is essential for personal protection in case of hazard situations or accidents because it acts as a barrier and gives extra protection and minimizes dangers. PPE ensures the safety of the workers themselves and those who are around them. To avoid the risk of accidents, all the employees must use PPE and the companies should mandate the workers to use PPE and should arrange training to inform the employees the usefulness of PPE and to ensure that the employees can use the PPE in a proper way. To find out the scenario in different chemical sectors, questions were asked regarding awareness and use of PPE. The scenario is shown in Figure 8.

In the answer to the question, “Do all the workers and officers use PPE in your plant?”, 60% responded negative, 20% were not sure and 20% response was positive. This indicates the lack of awareness and negligence of using

PPE in most of the employees. For the question, "Do your plant arrange training regarding awareness of using PPE?", 90% responded "Yes" and the remaining said otherwise. This implies that majority of the plants are conscious about employee's health and occupational safety. Moreover, to answer to the question, "Do you think using PPE reduce the fatality rate against chemical accidents?", 90% replied "Yes" and 10% had doubt. This indicates that most of the employees are aware of the usefulness of PPE.



(a) **(b)** **(c)**

Figure 8: Awareness of using PPE (a) Uses of PPE among employees, (b) Plant arrange training regarding awareness of using PPE, (c) PPE reduce the fatality rate against chemical accidents.

4. DISCUSSIONS

This article emphasizes on finding out different types of chemical accidents occurrence probability, awareness of chemical safety rules and regulation among the employees and the awareness of using PPE in the vast chemical sectors. So, our results provide practical scenario about the preparedness of different plants against chemical accidents. According to our survey in case of chemical occurred accidents, probability of fire was higher than the probability of explosion and the probability of toxic release was surprisingly low in different chemical sectors. To justify the statement, it's important to consider several factors that can influence the likelihood of these events. Many chemicals used in various industries are flammable or combustible. Flammable liquids, gases, and solids are more commonly encountered in chemical sectors compared to highly explosive materials Therefore, the likelihood of a fire occurring in the presence of combustible materials may be larger than the likelihood of an explosion (Darbra, Palacios et al. 2010). Sparks, flames, or high temperatures are common ways in which fires are ignited. While it is possible to encounter an ignition source that can cause an explosion in an industrial environment, the likelihood of encountering an ignition source that can cause a fire is far higher (Lake and Christianson, 2020). The risk of fires occurring in industrial settings is typically reduced by the use of severe safety measures, engineering controls, and fire prevention systems. The use of fireproof materials, cautious storage and handling, explosion-proof valves, and stringent protocols are all part of these safety measures. A decrease in the likelihood of explosions during fire occurrences is one benefit of taking such precautions (Chen et al., 2019). As a result, it's clear that both public and private organizations need to put more resources into fire safety measures and staff education.

Standardized safety measures and containment systems are in place in the chemical industry to limit the spread of hazardous materials. The use of safety equipment, adequate ventilation, and stringent storage and handling protocols are all examples of the kind of precautions that may be taken. By prioritizing safety, we can reduce the likelihood of toxic releases (Darbra, Palacios et al. 2010). Risk assessments are commonly used in the chemical industry to pinpoint potential dangers and establish effective preventative measures. By focusing on risk management strategies such process safety management systems, the likelihood of harmful emissions can be greatly reduced by addressing the potential leak, spill, or release sources (Polorecka et al., 2021). The safe handling, storage, and transportation of hazardous substances necessitate that chemical industries adhere to stringent norms and standards imposed by regulatory agencies. The likelihood of toxic releases can be reduced and preventative efforts can be encouraged if these rules are followed (Khanna and Damon, 1999).
Property damage, environmental remediation, cleanup costs, work interruption, legal fees, and reputational harm are just some of the damages that can occur from chemical accidents (Murphy 2017). Water, soil, and air pollution are only a few examples of the severe environmental damage that can result. Cleanup operations, ecological rehabilitation, and regulatory fines all contribute to the substantial cost of environmental remediation and restoration. Additionally, workers, emergency personnel, and residents in the area could all be put at risk. The cost of treating injuries, dealing with long-term health problems, and paying for rehabilitation services can add up to a significant amount even if fatalities are minimal. In addition to individuals, healthcare systems, insurance companies, and governments could be affected by these expenses.

Chemical accidents can cause problems not just for the company itself, but also for its suppliers and competitors. Delays in production, lost inventory, supply shortages, and lower revenue are all possible outcomes. Disruptions to commerce can cause economic losses that are felt far from the initial accident site. It frequently leads to regulatory inquiries and judicial proceedings. Companies risk heightened government scrutiny, regulatory fines, and litigation from affected individuals (Thornton, Gunningham et al. 2005). These legal and regulatory consequences can lead to significant financial burdens and further economic losses. So, although in case of accidents the fatality rate was lower because of the safety maintain in operations but the economic losses were huge in different chemical sectors. Oil and gas industries were more at risk because the probability of chemical accidents was higher than any other chemical industries. This suggests that the authority of gas and oil industry should be more cautious and take more preventive steps against chemical accidents to mitigate the probability of occurrence.

Moreover, 50% respondents were doubtful of their plants following all the safety rules and regulations. This clearly demonstrated the negligence of the employees of their plant following rules and regulations. A large percentage of the respondents were aware of the existing safety rules and regulations and also a large number of participants mentioned that their plants have safeguard for the prevention of chemical accidents. Due to high occurrence of chemically occurred accident, it is not surprising that the majority of chemical plants have their safety rules and safeguard to mitigate losses.

Meanwhile, the majority of the respondents answered that their plants didn't provide safety training to all the employees against the countermeasure of accidents, although they were eager to receive the safety training. This suggests that the Plants authority should be informed about the usefulness of organizing safety training to help the employees recognize hazards and measures to correct them. Half of the respondents said that they didn't have enough training and majority of them were eager to receive the training.
Although majority of the respondents were aware of the effectiveness of PPE in reducing the fatality rate in case of accidents but the survey showed that 60% of the employees had reluctance of using PPE. But most of the plant authority provided opportunities for the employees to be aware and trained of using PPE.

5. CONCLUSIONS

This survey based study provides insights about possibility of hazardous situation in any chemical and process plant and their preparedness regarding these. Chemical incidents are more likely to occur in the oil and gas industry than in any other chemical industry, according to the study. In certain chemical sectors, the chance of fire was greater than the probability of explosion, whereas the probability of hazardous leakage was surprisingly low. Fifty percent of those polled didn't even know if their facilities followed all of the applicable chemical safety laws. 80 percent of respondents agreed that greater training was needed for chemical accident prevention countermeasures, however the majority of plants did not see the value in doing so. Using personal protective equipment (PPE) in plants is a no-go for 60 percent of those who took the survey. This suggests that most workers are not aware of the importance of PPE or are too lazy to use it. A new law should be introduced mandating compliance with safety standards and regulations in all chemical industries. A regulatory agency might be established to make sure these plants are following safety rules. Personal protection equipment (PPE) should be mandated by legislation for all workplaces. In order to promote prevention, readiness, and effective response tactics in the case of a chemical accident, it is crucial to increase the public's awareness of the issue. It is possible to greatly reduce the risk of accidents occurring in the first place by teaching people about the potential hazards of chemicals, safe methods of handling and storing them, and the significance of adhering to safety measures. All facilities should make certain their workers receive enough safety training and understand its significance. Government agencies, non-governmental organizations, educational institutions and industry stakeholders all have to play a role in raising chemical safety awareness. A better understanding of chemical risks and the ability to respond efficiently in the event of an accident can be achieved by well-targeted campaigns, training programs, and the transmission of reliable information. Authorities and investigation boards can be established to determine the root causes of chemical accidents and provide recommendations and guidelines for avoiding such disasters in the foreseeable future. While chemical accidents are a serious concern, we can minimize the occurrence of such incidents and mitigate their potential impact but by fostering awareness and promoting safety culture. Prioritizing chemical and process safety, educating ourselves and others, and working to make the world a safer place is the responsibility of everyone.

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