Heliyon 9 (2023) e13472

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Explaining of the experts' points of view about the types and importance of man-made hazards in Iran's process industries: A qualitative study

Iman Farahi-Ashtiani [a], Katayoun Jahangiri [a,b,*], Sanaz Sohrabizadeh [c], Reza Gholamnia [d], Mohammad Reza Rasouli [e]

[a] *Department of Health in Emergencies and Disasters, School of Public Health and Safety, Shahid Beheshti University of Medical Sciences, Tehran, Iran*
[b] *Safety Promotion and Injury Prevention Research Center, Shahid Beheshti University of Medical Sciences, Tehran, Iran*
[c] *Air Quality and Climate Change Research Center, Shahid Beheshti University of Medical Sciences, Tehran, Iran*
[d] *Department of Health, Safety and Environment (HSE), School of Public Health and Safety, Shahid Beheshti University of Medical Sciences, Tehran, Iran*
[e] *Department of Industrial Engineering, Iran University of Science and Technology, Tehran, Iran*

ARTICLE INFO

Keywords:
Process industries
Qualitative study
Man-made hazards
Iran

ABSTRACT

Introduction: Process industries may have different hazards that can cause serious injury to humans, the environment, and the economy. Considering the importance of man-made risks in process industries, Experts' Points of View should be considered to apply risk reduction strategies Hence, the present study was performed to explain the views of experts regarding the types and importance of man-made hazards in process industries.
Materials and methods: This study was conducted using a qualitative method of directed content analysis with a deductive approach. The participants included 22 experts in the field of process industries. The selection of samples started purposeful and continued until data saturation. Data collection was done through semi-structured interviews.
Results: Based on experts' points of view, 5 man-made hazards in process industries were classified into 14 subcategories. The man category was divided into three subcategories: human error, technical knowledge error, and management error, the Material category was divided into 3 subcategories of leakage and rupture, chemical properties, physical properties, Medium category was divided into two sub-categories of incorrect location selection and placement and harmful environmental factors, Machines category was divided into three sub-categories of failure in design, failure in Preventive Maintenance (PM), failure in Safety Instrumented System (SIS), and the Methods category was classified into three sub-categories: defects in inspection, defects in information, defects in executive instructions.
Conclusion: Technical training to reduce personnel errors, conducting risk-based inspections to control leaks and possible ruptures, careful design and site selection in the initial phase of the project, is recommended. The use of engineering methods and artificial intelligence to obtain the risk number and control methods to reduce the harmful effects of risks can be helpful.

* Corresponding author. Department of Health in Emergencies and Disasters, School of Public Health and Safety, Shahid Beheshti University of Medical Sciences, Tehran, Iran.
E-mail address: k.jahangiri@sbmu.ac.ir (K. Jahangiri).

https://doi.org/10.1016/j.heliyon.2023.e13472
Received 30 October 2022; Received in revised form 23 January 2023; Accepted 1 February 2023
Available online 4 February 2023

1. Introduction

In Process industries the production processes are continuous. Such industries have many risks that can cause serious harm to humans, the environment, and the economy. range of these industries includes petrochemical industries, copper steel industries, etc. [1,2]. In the past decades, the need to change the control process and improve safety in process industries has increased a lot [3]. In this view, the need to apply a new type of process safety management increases, because we are facing new man-made crises in industries, the occurrence of which will result in irreparable financial, human, and environmental losses [4]. Previous research has demonstrated that in the last two decades, on average, 17% of important industrial accidents are related to process industries, which is a high percentage [5–7]. During the last decade in Iran, more than 35 important accidents (with more than 40 people killed and more than 40 injured) have happened in process industries. From the examination of the order and sequence of accidents, it is clear that the number of accidents in process industries has increased since 2010, which can be caused by the increase in the complexity of the process and the lack of preparation to respond to accidents, as well as the lack of adopting disaster risk reduction strategies [8]. Due to the development of process industries, the potential of industrial accidents increases [9,10]. Improper response to risks and their consequences on human resources in process industries causes financial costs and many injuries [11,12]. Considering the different components of risk, i.e. risk, vulnerability, and capacity, requires accurate identification of hazards affecting these industries so that appropriate interventions can be made by setting priorities to prevent the unfortunate consequences of accidents [13]. To respond to accidents, there are defined scientific methods that identify the types of hazards as the first step [14,15]. The 5 M model has been used in the identification and classification of risks, but in this model, the details of the sub-categories of risk have not been determined, therefore, we tried to extract the subcategory of each of the categories of this model using the qualitative method. Hence, this study was performed to explain the views of experts regarding the types and importance of man-made hazards in process industries.

2. Materials and methods

2.1. Study design

The present study is a qualitative study of the type of directed content analysis with a deductive approach, which is used to analyze the data and interpret its meaning to discover the effective factors, obstacles, facilities, and description of the studied phenomenon [16]. In directional content analysis, by assuming some concepts and generalizing the title of the classes, the text of the interviews is analyzed and changes are applied to the classes wherever necessary. The outstanding feature of this approach is that the initial coding is done based on previous findings, but in the process of data analysis, it is possible that new categories or fields can be obtained from the data [17]. This study was conducted between December 2021 and May 2022.

2.2. Settings

The research setting of a qualitative study is the place where people's experiences are formed [18]. In this research, the Center for Environmental and Labor Health of the Ministry of Health, specialized departments of HSE, and passive defense, and disaster management of the Ministry of Petroleum and Process Industries of Iran were selected as the research environment.

2.3. Sample selection

A Purposive sampling method was used to select the participants. In this method, researchers consciously choose people who have the desired characteristics or are rich in information in the field of research [19]. The selection criteria of participants in this research were to have knowledge in the field of process industries and at least 4 years of executive experience in process industries in one of the following 5 groups:

1 Employees and operational managers of refineries
2 Employees and managers of the Ministry of Oil
3 Employees and managers of national oil and gas companies and their subsidiaries
4 Disaster risk reduction experts in the health system
5 Related university professors

Sampling continued until data saturation was reached. Saturation means that by continuing to collect data, the obtained data are actually a repetition of the previous data and no new information is obtained [19]. Before going to the country's National Petrochemical Industries Company and related research centers, the participants (selection of key informants and researchers) were contacted and if they agreed to participate in the study, the necessary arrangements were made to go to their workplaces, and the data was collected. The only criterion for withdrawing from the present study was the unwillingness of the participants to continue participating in the study. Based on this, 22 face-to-face interviews were performed.

2.4. Data collection

At first, in order to obtain general concepts, 4 unstructured interviews were conducted, and then, using the interview guide, 18 semi-structured interviews were performed face-to-face. The interviews were conducted in a calm environment where the participant felt comfortable. The interviews started with simple and general topics and were gradually directed to specific questions based on the answers given. Some of the questions asked were as follows: In your opinion, what are the main hazards of Iran's process industries? What are the man-made hazards of Iran's process industries?

New topics in each interview, as well as topics that were less discussed in the interviews, formed the questions of the subsequent interviews, and this process continued until the last interview was conducted and data saturation was reached. All the interviews were done by setting a previous time and choosing the place of the interview according to the opinion of the participants. After obtaining the permission of the participants of the interviews by a digital recording device and to increase the accuracy of the obtained data, the transcription of the interviews was done immediately after the completion of each interview. The duration of the interviews was between 25 and 75 min (an average of 45 min). In all stages of the study, things like informed consent, the confidentiality of information, and the right to withdraw from the study at any time were respected.

2.5. Data analysis

In order to analyze the qualitative data, the content analysis method was used simultaneously with the data collection. The method of content analysis in this research was guided content analysis. For this purpose, the initial coding was started according to the selected conceptual framework, but the data analysis was done at the latent level to enable deep analysis of the meanings of the text instead of the obvious and apparent aspects. For a general understanding of the content of the interviews, first, the recorded file was listened to several times and then the transcription was done. The transcription of the interviews was done at a short distance from them. To prevent data deletion, the text of the interviews was returned to the interviewees to control the text. By reviewing the text of the interviews several times, a deep acquaintance with the data was made, and their analysis and synthesis were done. The interviews were categorized as units of analysis based on common meanings and concepts, and the interview text was divided into semantic units. Semantic units were summarized with the approach of reduction and condensation, and categories, subcategories, and codes were explained. The transcription process was such that several codes were compared in terms of differences and similarities and categories and subcategories were made. In order to deeply understand the concepts and prevent surface coding, coding and classification of concepts were implemented completely manually on paper sheets.

2.6. Trustworthiness

The criteria of credibility, confirmability, dependability, and transferability were used to check the reliability of the study data [20]. Allocation of sufficient time for data collection and analysis and long-term interaction of the researchers with the participants were considered to achieve the credibility of the data. Also, member checks and peer checks were used for data credibility. In the member check, after analyzing the results, to determine whether these results were in accordance with the experiences of the participants, a summary of the initial results was sent to a number of them and their accuracy was checked. In the peer check, parts of interviews, the initial set of codes, and subcategories in the research group were examined by the researcher, supervisors, and consultants. To achieve verifiability, the researchers tried to be neutral toward the study data and get their opinions about the findings through note-taking. In this research, dependability does not mean repeatable results in the field or context of the research, but it was tried to consider different points of view through the triangulation method of the research team and in the data analysis. Data transferability was obtained by mentioning all the stages of conducting the study, including the method of selecting participants, the method and tools of data collection, and the method of data analysis and interpretation.

Table 1
Demographic characteristics of the participants.

Variable	Group	Number (%)
Gender	Female	2 (9.1%)
	Male	20 (90.9%)
Education	Master	13 (60%)
	PHD	9 (40%)
Job Title	Employees and operational managers of refineries	10 (45%)
	Employees and managers of the Ministry of Oil	3 (14%)
	Employees and managers of national oil and gas companies	3 (14%)
	Disaster risk reduction experts in the health system	2 (9%)
	Related university professors	4 (18%)
Age	30–38	6 (27%)
	38–46	11 (50%)
	46–54	5 (23%)
Job Experience	4–12	5 (23%)
	12–20	10 (45%)
	20–28	7 (32%)

Table 2
Codes, subcategories, and main categories of man-made hazards.

Category	Subcategory	Example of Codes
Man	Manager Errors	Lack of commitment of the senior management of the organization
		Lack of commitment to process safety
		Lack of organizational safety culture
		Lack of individual safety culture
		Lack of attention to change management
		Lack of coordination between personnel
	Technical Error	Lack of skill
		Lack of knowledge
		Incompetence
		Lack of experience
		Insufficient process knowledge
		Lack of material safety training
	Human Error	Detection error
		Communication error
		Distractions
		Reactive error
		Lack of operator attention
		Operator negligence
		Deliberate error
		Careless
Material	Leakage and Rupture	The presence of hydrogen gas
		Presence of gas with high concentration
		Leakage of toxic substances
		Chemical spill center
		Chemical rupture center
		Toxic vapor cloud
		Flammable vapor cloud
		Explosive vapor cloud
	Chemical Properties	The degree of toxicity of substances
		Flammability of the material
		The degree of activity of the material
		Lack of material quality
		Presence of incompatible materials
		Interactions between substances
		Chemical interaction
		Mixing chemicals
	Physical Properties	Temperature characteristic
		Compressive feature
		Flow characteristics of the material
		Temperatures
		Boiling point
		Freezing point
		Flash point
Methods	Defects in inspection	Absence of an inspection system based on RBI[1]
		Inappropriate work permit
		Lack of compliance audit
		Failure to properly test equipment
		Inappropriate CM[2]
		No gas leak test
	Information Defects	Lack of correct information about material safety
		Lack of correct information regarding process safety
		Lack of correct information about equipment safety
		Lack of integrated information system
		Absence of material database
	Deficiency in executive order	Lack of relevant instructions
		Compilation of incomplete instructions
		Non-exhaustive instructions
		Unprincipled compilation of instructions
		Incorrect job description
		Lack of localization of instructions
Machines	Design Failure	Non-standard equipment design
		Improper design of indicators
		Improper construction
		High tank height
		The Long distance between ducts
		Lack of safety layers in the design
	Failure in PM	Deformity
		No maintenance

(*continued on next page*)

Table 2 (*continued*)

Category	Subcategory	Example of Codes
	Failure in SIS	Lack of periodic service Connection reliability Excessive wear and tear of equipment Equipment breakdown Equipment explosion Equipment damage Failure of the safety valve Delay in safety valve work Late opening of the switch valve Vents not working properly Barriers error Safety gauge failure Safety gage delay
Medium	Incorrect location and placement	Improper infrastructure Incorrect selection of equipment Unscientific placement Wrong placement of unsafe machinery Unexplored closed space, choosing a place with strong wind Choosing a site with a high altitude from the sea Choosing a site with environmental contamination Choosing a site with air pollution Choosing a site with a steep slope Site selection in an unsuitable climate
	Harmful Environmental Factors	Sound of Environment Hot work Radiant heat High temperature High steam pressure Source of electricity spark Unsafe hot operation Light Vibration

[1] Risk Based Inspection
[2] Configuration management

2.7. Ethical consideration

This study is a part of a specialized doctoral dissertation at Shahid Beheshti University of Medical Sciences in Tehran with code of ethics IR.SBMU.PHNS.REC.1400.068 is approved. In order to comply with ethical considerations, in the beginning, informed consent was obtained orally from all participants and they were assured that the interviews would remain confidential without mentioning names and personal details.

3. Results

In this study, 22 participants participated in the research, whose demographic information is presented in Table 1.

In the present study, in the initial writing, 811 primary codes were identified, and after removing duplicate codes and cleaning, the number of final codes reached 237 codes. After reviewing and analyzing the data, 5 main groups of man-made hazards were introduced to the research participants by using the 5 M model. Then the participants were asked to express their opinion about the types of man-made hazards in each category. After interviewing and obtaining the opinions of all participants, the main man-made risks of process industries were classified into 14 subcategories. The Man category is divided into three subcategories: human error, technical knowledge error, and management error. The Material category is divided into 3 sub-categories of leakage and rupture, chemical properties, physical properties, Medium category is divided into two sub-categories of incorrect location selection and placement and harmful environmental factors, Machines category was divided into three sub-categories of failure in design, failure in PM (Preventive Maintenance), failure in SIS (safety instrumented system), and Methods category were classified into three sub-categories: defect in inspection, defect in information, defect in executive instruction. Codes, sub-categories, and main categories of man-made hazards of process industries are shown in Table 2.

3.1. Man

One of the main categories of this research was Man, which has 3 subcategories of managerial error, technical error, and human error. According to the opinion of the participants, human error was the most important subcategory. Personnel engaged in process industries for unintentional reasons such as distraction and stress can cause errors in the process that lead to a disaster. Sometimes this error can occur intentionally and with planning and with the purpose of sabotage, and sometimes it is unintentional and is caused by a lack of knowledge or experience, or by repeating a task too much, which causes the device operator to make an error and cause harmful consequences. Management errors such as lack of commitment of the senior manager of the organization to comply with safety requirements and lack of safety culture can also lead to accidents. An error based on a defect in technical knowledge can also be an accident-causing process in industries. For example, the lack of training to work with devices and equipment makes the operator not know what to do in an emergency.

"A person intentionally commits a violation. In fact, we use this as an example of a violation: the gentleman should go and check the line and then sign the permit, but he didn't". p10

"There was an accident where a person slips for a moment, for example, instead of starting the first fan, he starts the second fan, and the fan spins and hits the person's neck." p12

"Or someone should check the gas pressure of the tank due to family problems, he was not paying attention, because he was busy and the tank exploded and the person himself was seriously injured". p17

3.2. Material

Another main category of this research is Material, which has 3 subcategories of leakage and rupture, chemical properties, and physical properties. In process industries, leakage and rupture are the most important hazard that can have a domino effect and cause secondary accidents. Leakage is the continuous release of materials from inside the pipes or system, which can cause ignition at that point, or if there are no safety layers, it can reach other parts and cause fires. Rupture refers to the release of materials in less time and with a higher flow rate, which can cause the creation of toxic and explosive clouds of vapors and massive explosions in the system. Chemical and physical properties of materials can also play a potential role in the occurrence of accidents. In many cases, due to the lack of familiarity of personnel with the chemical characteristics of materials and their safe storage, ignition or explosion occurs in process industries.

"The phenomenon of VCE-Vapor Cloud Explosion or explosive cloud mass; Now, what are the types of fires? We have a ball fire, which is the same background, and we have a pool fire, which is the background of releasing chemicals. Why? Because of a rupture or a leak in the high-pressure gas pipelines, the gas is ruptured into the atmosphere and if there is a spark source, that gas column becomes a fire column, which we actually call Jet-Fire". p8

3.3. Methods

Another title of the main categories of this research is Methods, which had 3 subcategories of defects in inspection, defects in information, and defects in executive instructions. According to experts, the most important sub-category of this section is inspection defects. Because the lack of inspections based on risk assessment and work permits will lead to many accidents in industries. According to the participants, the lack of attention of managers and officials to periodic inspections has also resulted in accidents. For example, not testing tanks before starting work and not having a work permit led to explosions that killed and injured many. Faults in the flow of information and a lack of integrated management systems can also disrupt the coordination process and lead to accidents. Not having a comprehensive recipe that describes the risks and different working conditions can make doing different work tasks a challenge.

"The absence of an inspection system, the absence of a risk-based inspection system (RBI), can be very challenging. All of these factors bring us to a critical point. Where is the critical point? It is the point where energy It is being ruptured and there is nothing to hold that energy anymore, why? Because all the layers that were supposed to hold this energy are practically destroyed". p9

3.4. Machines

The fourth main category is Machines, which has subcategories of failure in design, failure in PM, and failure in SIS. According to the participants, the most important subcategory of this section is design failure. In fact, when a site and devices are not designed and implemented based on safety principles, the system will suffer from many problems. For example, when the slope of pressurized pipes is not designed correctly, this process causes the deposition of hydrocarbon materials and over time causes wear and leakage of explosive or flammable materials. Also, the improper PM also causes cracks or failures Contingency in the equipment does not cover properly. Also, if the controller's safety tools do not work properly or act with delay, disaster will occur. For example, if the safety valve is opened late, the pressure inside the tank will increase and if it exceeds the internal resistance of the tank, the tank will explode.

"The process was such that the nitrogen injected above the tank causes an increase in pressure and also brings it to the UEL and prevents the explosion and prevents the tank from collapsing. That is when you suck with a pump and when you export, the tank will be in a state of collapse. Therefore, a nitrogen line is connected to it from above so that the top of the tank is inert and that collapse does not happen in the tank. Well, now the story was that the design test here was important". p10

3.5. Medium

The last main category of this research is Medium, which has two subcategories of incorrect location selection and placement and harmful environmental factors. The most important sub-category of this section is harmful environmental factors because if these factors are not properly identified and answered, they can affect the morale and physics of the human force and cause errors in the system and ultimately lead to becoming a crisis. These include excessive noise, high temperature, vibration, etc. Also, inappropriate selection of the site can cause many problems for the organization. For example, the atmospheric pressure is variant in different places, if our pressure vessels cannot withstand it, or if it wears out after a period of time and its resilience decreases, it can lead to an explosion.

> "Is it a hot environment or a warm environment, for example, let's say that the summer in Bandar Abbas is very different from the same refinery or petrochemical in Ardabil, in the same summer at the same time of the year, so there is definitely more volatility here". p14

4. Discussion

The results of the present study showed that the human factor plays a significant role in causing accidents in process industries. According to the present study, lack of education or Nonstandard education plays a big role in creating industrial crises. This research showed that human error is the most important factor in the category of human errors, the study of Saleh et al. (2012) also confirmed the results of this research [21]. This type of error can be a deliberate or inadvertent error caused by fatigue and distraction and diagnostic error. In the study of Azhdari et al. (2017), human error was the biggest cause of accidents with a contribution of 37.6% of refinery accidents [22]. In another study by Al-Khaldi in Bahrain (2017), behavioral errors of personnel and decision errors were declared to be the most important factors in creating disasters in process industries [23]. Other studies also confirmed this conclusion [24–26]. Therefore, control measures to reduce the risk in the field of human error are very important.

According to the opinion of the interviewers, management error which includes the lack of safety culture and lack of commitment of senior management to safety issues also plays an important role in the occurrence of industrial accidents. In a study performed in 2009 by Wu et al., it was shown that safety culture is an important factor that can cause complex accidents in process industries [27]. Also, a study by Goncalves Filho (2010) in Brazil considers the lack of safety culture as a major hazard for refinery industries [28]. This result is consistent with the results of our study.

Another result of this study is that leaks and ruptures can cause other accidents, the root causes of which include decay, improper maintenance and repair of equipment, and failure to inspect the internal pressure of pipes and pressure vessels. The study by Jia et al. in 2021 also confirmed this finding [29].

The present study also showed the existence of defects in the inspection systems, which include a lack of work permits, a lack of gas and vapor leakage tests, and a lack of risk-based inspections. The participants expressed that workers' negligence, ignorance, and violation can be controlled by risk-based inspection, and lack of inspection leads to accidents. For example, a person starts working without a work permit, which results in an accident. In a study by Cong GP (2013), it was concluded that inspection can reduce cost and human casualties in process industries and improve the performance of safety systems [30].

Among the other findings of this study, we can mention the failure in the design of systems and machines. Many of the interviewees stated this as the main factor in the occurrence of process accidents. The sentence "For example, if the pressure tank is not placed at a suitable height or its internal pressure is not accurately calculated, it can lead to failure and accidents." A study which was carried out by Moura R (2016), considers design failure as the cause of large industrial accidents and as a human factor [31]. In this study, this factor is considered under the machine category, because its destructive effect is caused by the operation of the machine. Of course, if we want to look at the incidents in a fundamental way, all cases originate from human error, which makes the work very difficult to analyze. Therefore, this case is against the conclusion and classification in our study.

Harmful environmental factors are another finding of the present study. High temperature, stress, created humidity, high work pressure and sound, and vibration are examples that the interviewers mentioned. A study conducted in 2001 by Li CY identified stress and job dissatisfaction as a factor in causing injuries and accidents [32].

5. Strength points and study limitations

One of the strongest points of this research was explaining the experiences of the stakeholders in Iran's process industries through a qualitative study because the researches that had been done in this field before were quantitative studies. One of the limitations of this research was the difficulty in accessing the participants to conduct interviews because people had to be selected who had sufficient scientific knowledge or experience in the field of safety in process industries. The number of experts in this field was limited and it was very difficult to get interview time from them. In addition, the strategic nature of these industries in Iran made it very difficult to access information.

6. Conclusion

Institutionalizing a safety culture, using a proactive approach instead of a response-oriented approach, using risk reduction strategies such as developing preparedness and response plan, holding drill sessions, and using simulation systems to train employees to reduce human error in process industries are suggested.

Performing risk-based inspections to control leaks and possible ruptures, paying attention to designing and selecting the site in the initial phase of the project, and using engineering methods and artificial intelligence to obtain the risk number and control methods to reduce the harmful effects of risks can be helpful.

Declarations

Author contribution statement

Iman Farahi-Ashtiani: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Katayoun Jahangiri: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

Sanaz Sohrabizadeh: Conceived and designed the experiments; Wrote the paper.

Reza gholamnia: Performed the experiments; Wrote the paper.

Mohammad R. Rasouli: Contributed reagents, materials, analysis tools or data; Wrote the paper.

Funding statement

This research work was supported by Iran National Science Foundation, Tehran, Iran. In addition, this project was supported by School of Public Health and Safety at Shahid Beheshti University of Medical Sciences, Tehran, Iran.

Data availability statement

The data that has been used is confidential.

Declaration of interest's statement

The authors declare no competing interests.

Acknowledgments

This qualitative study is part of the Ph.D. thesis with ID IR.SBMU.PHNS.REC.1400.068. By the way, the research team appreciates all the participants for providing their valuable knowledge and experiences.

References

[1] J. Kallrath, Planning and scheduling in the process industry, Spectrum 24 (3) (2002) 219–250.
[2] N.J. Duijm, et al., Management of health, safety and environment in process industry, Saf. Sci. 46 (6) (2008) 908–920.
[3] M. Kalantarnia, F. Khan, K. Hawboldt, Modelling of BP Texas City refinery accident using dynamic risk assessment approach, Process Saf. Environ. Protect. 88 (3) (2010) 191–199.
[4] M.C. Carneiro, G.P. Ribas, S. Hamacher, Risk management in the oil supply chain: a CVaR approach, Ind. Eng. Chem. Res. 49 (7) (2010) 3286–3294.
[5] Z. Nivolianitou, M. Konstandinidou, M. Christou, Statistical analysis of major accidents in petrochemical industry notified to the major accident reporting system (MARS), J. Hazard Mater. 137 (2006) 1–7.
[6] S. Kourniotis, C. Kiranoudis, N. Markatos, Statistical analysis of domino chemical accidents, J. Hazard Mater. 71 (1–3) (2000) 239–252.
[7] K. Kidam, M. Hurme, Statistical analysis of contributors to chemical process accidents, Chem. Eng. Technol. 36 (1) (2013) 167–176.
[8] M. Kangavari, et al., An application of failure mode and effect analysis (FMEA) to assess risks in petrochemical industry in Iran, Iran. J. Health, Saf. Environ. 2 (2) (2015) 257–263.
[9] S. Einarsson, M.J.R.a. Rausand, An approach to vulnerability analysis of complex industrial systems, Risk Anal. 18 (5) (1998) 535–546.
[10] I. Farahi-Ashtiani, et al., Promoting industrial safety based on safety culture's worker: SAIPA case study, J. Saf. Promot. Inj. Prevent. 7 (3) (2019).
[11] M. Sarani, et al., Challenges facing the health system in responding to mining accidents: the case of the zemestan-yurt mine explosion in Iran (2017), J. Occup. Health Epidemiol. 10 (3) (2021) 204–208.
[12] P. Shafiei Moghaddam, et al., Foresight of the consequences of the Hazmat Release from an oil Refinery on the surrounding urban community following an earthquake: a Natech scenario analysis, Disaster Med. Public Health Prep. (2022) 1–10.
[13] F. Fatemi, S. Moslehi, A. Ardalan, Preparedness functions in disaster: lesson learned from Tehran dust storm 2014, Nat. Hazards 77 (1) (2015) 177–179.
[14] S. Rathnayaka, F. Khan, P. Amayotte, Accident modeling and risk assessment framework for safety critical decision-making: application to deepwater drilling operation, Proc. Inst. Mech. Eng. O J. Risk Reliab. 227 (1) (2013) 86–105.
[15] S. Nematifard, et al., Identification of safe assembly points in emergencies in a gas Refinery of the south pars gas complex using fuzzy logic model, jorar 11 (4) (2019) 275–286.
[16] S. Elo, et al., Qualitative content analysis: a focus on trustworthiness, Sage Open 4 (1) (2014), 2158244014522633.
[17] B.M. Wildemuth, Applications of Social Research Methods to Questions in Information and Library Science, Abc-Clio, 2016.
[18] J. Corbin, A. Strauss, Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory, Sage publications, 2014.
[19] R. Jalali, Qualitative research sampling, J. Qual. Res. Health Sci. 1 (4) (2013) 310–320.
[20] I. Korstjens, A. Moser, Series: practical guidance to qualitative research. Part 4: trustworthiness and publishing, Eur. J. Gen. Pract. 24 (1) (2018) 120–124.
[21] J.H. Saleh, C.C. Pendley, From learning from accidents to teaching about accident causation and prevention: multidisciplinary education and safety literacy for all engineering students, Reliab. Eng. Syst. Saf. 99 (2012) 105–113.
[22] M. Azhdari, G. Monazami Tehrani, A. Alibabaei, Investigating the causes of human error-induced incidents in the maintenance operations of petrochemical industry by using HFACS, J. Occupat. Hyg. Eng. 3 (4) (2017) 22–30.

[23] M. Alkhaldi, C. Pathirage, U. Kulatunga, The Role of Human Error in Accidents within Oil and Gas Industry in Bahrain, in: 13th International Postgraduate Research Conference (IPGRC): Conference Proceedings, University of Salford, 2017.

[24] M. Mariana, T.R. Sahroni, T. Gustiyana, Fatigue and Human Errors Analysis in Petrochemical and Oil and Gas Plant's Operation, in: Proceedings of the International Conference on Industrial Engineering and Operations Management, Bandung, Indonesia, 2018.

[25] M. Jahangiri, F.Z. Derisi, N. Hobobi, Predictive human error analysis in permit to work system in a petrochemical plant, Saf. Reliabil. 138 (2014) 1007–1010.

[26] A. Ghasemi, F. Atabi, F. Golbabaei, Human error classification for the permit to work system by SHERPA in a petrochemical industry, J. Occup. Hyg. Eng. 2 (3) (2015) 66–73.

[27] T.-C. Wu, C.-H. Lin, S.-Y. Shiau, Developing measures for assessing the causality of safety culture in a petrochemical industry, Water Air Soil Pollut. Focus 9 (5) (2009) 507–515.

[28] A.P. Goncalves Filho, J.C.S. Andrade, M.M. de Oliveira Marinho, A safety culture maturity model for petrochemical companies in Brazil, Saf. Sci. 48 (5) (2010) 615–624.

[29] Q. Jia, et al., LPG leakage and explosion accident analysis based on a new SAA method, J. Loss Prev. Process. Ind. 71 (2021), 104467.

[30] G.P. Cong, et al., Study on the Dynamic Inspection for Decreasing the Losses and Costs Caused by Accidents of Fixed Equipment in Petrochemical Plants, in: Advanced Materials Research, Trans Tech Publ, 2013.

[31] R. Moura, et al., Learning from major accidents to improve system design, Saf. Sci. 84 (2016) 37–45.

[32] C.Y. Li, et al., Job stress and dissatisfaction in association with non-fatal injuries on the job in a cross-sectional sample of petrochemical workers, Occup. Med. 51 (1) (2001) 50–55.