Original Article

Factors Affecting Petrochemical Industry Preparedness in Fire: A Qualitative Study

Davoud Pirani[1], Reza Gholamnia[2], Zohreh Ghomian[3], Abbas Ebadi[4,5], Mohtasham Ghaffari[6], Naser Jamshidi[7], Davoud Khorasani-Zavareh[8]

[1]Department of Health in Disasters and Emergencies, School of Public Health and Safety, Shahid Beheshti University of Medical Sciences, [2]Department of Health, Safety, and Environment (HSE), School of Public Health and Safety, Shahid Beheshti University of Medical Sciences, [3]Safety Promotion and Injury Prevention Research Center, Department of Health in Disasters and Emergencies, School of Public Health and Safety, Shahid Beheshti University of Medical Sciences, [4]Behavioral Sciences Research Center, Life Style Institute, [5]Faculty of Nursing, Baqiyatallah University of Medical Sciences, [6]Department of Health Education and Health Promotion, School of Public Health and Safety, Shahid Beheshti University of Medical Sciences, [7]Passive Defense and Crisis Management Manager of the National Petrochemical Company, [8]Workplace Health Promotion Research Center (WHPRC), Department of Health in Disasters and Emergencies, School of Public Health and Safety, Shahid Beheshti University of Medical Sciences, Tehran, Iran

ORCID:

Davoud Pirani: 0000-0002-5984-9258
Reza Gholamnia: 0000-0002-7891-4801
Zohreh Ghomian: 0000-0002-3644-7379
Abbas Ebadi: 0000-0002-2911-7005
Mohtasham Ghaffari: 0000-0003-1756-5297
Naser Jamshidi: 0000-0002-1785-2408
Davoud Khorasani-Zavareh: 0000-0001-6265-8148

Abstract

Background and Objectives: The preparedness of petrochemical industries against disasters is important to control risks, reduce losses and possible damages. Studies have shown that preparedness is an important factor in the disaster response phase. This study aimed to explore the factors influencing industry preparedness in fire. **Methods:** This study was conducted from July 2020 to December 2021, with a qualitative case study design. The population included 22 people including 12 crisis managers, three Health, Safety, and Environment chief officers, two operational commanders in the fire department, two policymakers and three university professors. The data were collected through semi-structured interviews and purposeful sampling, which continued until saturating the data. The strategies recommended by Guba and Lincoln were used for evaluating the trustworthiness of the data. The data were analyzed using the conventional content analysis method according to the method suggested by Graneheim and Lundman. **Results:** The effective components of the petrochemical industry preparedness for fire were classified into six main categories and 16 subcategories. Categories and subcategories covered fire characteristics (nature and chain of fire), policy-making (regulations, incident information documentation, and incident insurance incentives), and management factors (commitment and leadership, incident command, communication and information, and planning). The others involved support factors (equipment supply, coordination and cooperation, and training and awareness), safety culture (risk management, monitoring and auditing, inherently safe design), and sanction consequence (software and hardware). **Conclusions:** Many factors affect the petrochemical industry's preparedness for fire. Adopting effective management and appropriate policy regarding preparedness with strategies for promoting and developing a safety culture can improve the preparedness of petrochemical industries in disasters.

Keywords: Chemical industries, disasters, emergencies, fires, industrial accidents

Introduction

Petrochemical industries play an important role in the economy of the world countries.[1] Due to the presence of a wide range of hazardous materials, as well as operation at high temperatures and pressure, and complex hardware systems, the industries are

Address for correspondence: Dr. Davoud Khorasani-Zavareh, Workplace Health Promotion Research Center (WHPRC), Department of Health in Disasters and Emergencies, School of Public Health and Safety, Shahid Beheshti University of Medical Sciences, Tehran, Iran.
E-mail: davoud.khorasani@gmail.com

Access this article online

Quick Response Code:

Website: www.archtrauma.com

DOI: 10.4103/atr.atr_46_22

How to cite this article: Pirani D, Gholamnia R, Ghomian Z, Ebadi A, Ghaffari M, Jamshidi N, *et al*. Factors affecting petrochemical industry preparedness in fire: A qualitative study. Arch Trauma Res 2022;11:189-98.

Received: 09-08-2022, **Revised:** 15-01-2023,
Accepted: 15-01-2023, **Published:** 28-02-2023.

known as incident-prone industries, in which many incidents and disasters occur annually.[2] The incidents in oil, gas, and petrochemical industries possess high damage capacity so that they can lead to major damage to the environment and equipment, as well as the injury, disability, and death of individuals.[3] The results of the previous studies indicated that a great rate of the important incidents (17%) is related to petrochemical industries during 1985–2002.[4] In addition, as an example, the trend of incidents in petrochemical industries in many middle-income countries is increasing.[5]

As an example, fire in Bandar Imam and Bouali Sina petrochemical companies of Iran, and 12 other ones over a 5-month period in 2016 in petrochemical complexes are among these incidents.[6,7] Fire is one of the most dangerous incidents and emergency conditions, which seriously threats the health of the industry personnel and surrounding population, along with imposing financial damage.[8] Preparedness measures and serious decisions to reduce fire and explosion risks for saving human life can help to limit damage to industry facilities and environment.[9] Natural and human-made hazards, and investment, security, and financial issues are considered as one of the crises and risks at the top of the petrochemical industries. The disasters are almost unpredictable, most of which can be prevented very little. Process incidents such as petrochemical and refinery ones occur widely worldwide.

The evaluation of major industrial accidents reflects that the unpreparedness of organizations for emergency conditions can enhance incident consequences significantly.[10] Not coping with incidents and crises in industry appropriately leads to serious hurts to the health of those working in the industrial zone and surrounding residents.[11] Hosting different economic damages in industry is related to disasters.[12] The preparedness during disasters and incidents can highly prevent and diminish probable damage rate.[13] Strengthening design and construction standards in industrial facilities, as well as planning for emergency conditions, occupational health and safety regulations, and continuous risk management are some of the critical components in industry preparedness.[14] Multiple incidents in industries, high cost and time, and need for a large amount of sources[8] reveal the necessity for the preparedness of petrochemical complexes against postdisaster fire. To the best of our knowledge, based on a comprehensive literature review, Limited number of studies have dealt with the issue of preparedness of industries against disasters in the world. Most of them were quantitative and evaluated the consequences of accidents. In Iran, few studies have investigated the preparedness of petrochemical industries against disasters. Due to the lack of knowledge in this field, this study uses a qualitative method to explain and explore the elements and components that affect the preparedness by experiences and knowledge of petrochemical industry managers. Qualitative research helps generate hypotheses as well as further examine and understand quantitative data. One of the strengths of qualitative research is its ability to explain processes and patterns of human behavior that are difficult to quantify. Qualitative research collects participants' experiences, perceptions, and behaviors.[15] Thus, the present study aimed at exploring factors affecting petrochemical industry preparedness in fire in Iran.

Methods

Study design

This qualitative study was carried out based on the qualitative content analysis method recommended by Graneheim and Lundman from July 2020 to December 2021.[16]

Participant selection

Twenty-two of the participants were selected based on purposeful and maximum variety of sampling methods. The inclusion criteria included having practical experience or theoretical knowledge regarding the petrochemical industry preparedness, and the willingness to participate in the interviews. However, those individuals who refused to give informed consent and had the unwillingness to participate in the study were excluded from the study. The participants included two national crisis managers, three Health, Safety, and Environment (HSE) senior managers, 12 crisis managers in petrochemical companies, and two operational commanders in fire department with the knowledge and/or practical experience in the petrochemical industry preparedness during disasters, and three university professors.

Data collection

Three unstructured interviews were first conducted to gain general concepts. Then, 19 individuals were interviewed face-to-face using the semi-structured interview guideline. To make the participants feel comfortable, the interviews were conducted in a quiet environment, such as the participants' work environment or everywhere they preferred. The interviews began with general questions on the national approaches to petrochemical industry preparedness and continued with special ones about the factors of the preparedness during fire, as well as obstacles and challenges ahead, and suggestions for improving the preparedness. The core axes of the interviews included the following questions. What are the components influencing the petrochemical industry preparedness based on your experiences? What challenges do industries face in preparedness according to your experience? What do you think about the obstacles of petrochemical industry preparedness? What elements do you recommend to enhance industry preparedness based on your experience? Then, concepts were saturated by asking the questions such as "How," "Why," and "Please explain more." New issues in each interview and those less addressed in interviews were considered as the questions of the next interviews, which was continued until implementing the last interview and reaching data saturation. They lasted 25–60 min (mean: 42 min), while the duration of one interview was more than 75 min. Verbatim transcription of all of the interviews was performed by the main researcher.

Data analysis

The data were analyzed simultaneously with their collection. To this end, the content analysis was used using the Graneheim and Lundman method (five stages).[16] In this study, 1936 initial codes were identified, which decreased to 674 final ones after eliminating duplicate codes and summarizing. To acquire a general understanding of the interviews, the principal researcher (DP) frequently heard the existing interviews. After transcribing and typing, the final text was read repeatedly and examined with the recorded file to generate and transcribe the initial codes. In the second stage, all materials were extracted and gathered as a unit text forming the unit of analysis. The next stage was related to the division of the text into meaningful units. Regarding the fourth stage, the units were summarized and labeled using codes. Then, the codes were divided into subcategories based on the similarities and differences. The data analysis continued until generating main categories.

Rigor

The four strategies recommended by Guba and Lincoln (credibility, confirmability, dependability, and transferability) were applied to ensure the trustworthiness of the present study.[17] Regarding the prolonged engagement, the researcher was actively engaged in the petrochemical field for 4 months while making observations and compiling field notes continually.

As for triangulation, multiple researchers were to evaluate the study, which brings different perceptions of the inquiry and helps to strengthen the integrity of the findings. Also, for data triangulation or informant's triangulation, different sources of data or instruments such as interviews, and field observation were utilized to enhance the quality of the data from different sources.

In order to check the members, the analyzed and interpreted data were sent back to the participants to evaluate the interpretation and change the interpreted data if the participants were unsatisfied. Negative case analysis was used when the data collected from the inquiry was inconsistent with the researcher's expectations, leading to an improvement in the credibility of the study.

The data transferability was achieved by mentioning all of the study stages such as sampling and data analysis methods, and data collection instrument and approach. Reflexive journal or practice, along with the integrity of research findings was used to assess the confirmability of data. In this regard, the researcher's background and interest in the subject and maintaining the documents of the study were used for checking the confirmability of data.

The context of the interviews, codes, and extracted categories and themes were reviewed by the research team and other professional colleagues in the field of qualitative research. Using sampling with a maximum variation, the researchers were able to collect a wide variety of different comments, observations, and interpretations.

Table 1: Demographic information of the participants on the factors influencing the industry preparedness against postdisaster fires

Participant's characteristics	Frequency (%)
Position	
HSE chief officer	3 (13)
Crisis manager in petrochemical company	12 (54)
Operational commander in fire department	2 (10)
Policy maker	2 (10)
University professors	3 (13)
Sex	
Male	21 (96)
Female	1 (4)
Age	
26-34	5 (21)
35-43	7 (33)
44-52	3 (13)
53-60	7 (33)
Work experience (years)	
2-7	3 (13)
8-13	7 (33)
14-19	12 (54)

HSE: Health, Safety and Environment

Results

In this study, 22 participants were selected. Table 1 shows the demographic information of the participants. Following data analysis, the components influencing the petrochemical industry preparedness in fire were classified into six main categories and 16 subcategories. Table 1 shows the demographic information of the participants. Following data analysis, the components influencing the petrochemical industry preparedness in fire were classified into six main categories and 16 subcategories. The categories included fire characteristics (subcategories: The nature and chain of fire), policy-making (regulations, incident information documentation, and incident insurance incentives), management factors (commitment and leadership, incident command, communication and information, and planning), support factors (equipment supply, coordination and cooperation, and training and awareness), safety culture (risk management, monitoring and auditing, and inherently safe design), and sanction consequence (software and hardware) [Table 2].

Fire characteristics

Fire nature

The participants frequently referred to the type and characteristic of fire as the components in the petrochemical industry preparedness. The preparedness against fire crisis should cover the types of fire such as pool and explosion ones, as well as small and large fire extents. Further, the interviewees mentioned the terribleness of fire, as well as its importance in the industry compared to the other crises.

"..Fire is a fearful crisis for the industries. The managers experiencing the incident know how much damage dose this

Table 2: Codes, subcategories, and categories of effective factors on the petrochemical industry preparedness during fire in Iran

Category	Subcategory	Example of codes
Fire characteristic	Fire nature	Fire extent
		Type of fire
		Fire severity
		Harmfulness of fire
		Panic over fire
	Fire chain	Eliminating fire cause
		Controlling spark/fire sources
		Stopping fire chain reaction
		Detecting leak
Policy making	Regulations	Existence of binding laws in the crisis field
		Development of operating instructions
		HSE and crisis regulatory by-law
		Rules related to tax incentives
		Incentive and punitive laws
	Incident information documentation	Documenting unsafe processes
		Having an incident and crisis-recording system
		Utilizing experiences and lessons learned
		Preparing site map, as well as the diagrams of critical conditions
		Correct data for data mining
	Incident insurance incentives	Government incentive laws
		Insurance discount on preparedness topics
		Incident insurance coverage
		Employer/contractor insurance incentives
		Insurance waiver for hiring specialists
Management factors	Commitment and leadership	Practical commitment of managers to industry preparedness
		Lack of priority for incidents and disasters by managers and officials
		Priority of preventive approach over the reactive one
		Safety approach and attitude of managers and employees
	Incident command	Existence of incident command system
		Preparation and communication of job description to stakeholders
		Multiplicity of the officials making decision for crisis
		Lack of a unit terminology for incidents
		Formation of specialized crisis teams
	Communication and information	Communication with adjacent firefighting units
		Proper information of involved employees and managers
		Accurate information system inside and outside the site
		Presence of the coordination committees of personnel and managers
		Cohesive organizational communication
	Planning	Planning for the preparedness for the worst possible scenario
		Lack of ERP in industries
		Futures studies programs for preparedness promotion
		Monitoring programs of industry preparedness
		Research in the crisis field
Support factors	Equipment supply	Hardware equipment for preparedness
		Software equipment for preparedness
		Allocating annual budget for preparedness programs
		Purchasing advanced fire-extinguishing equipment
		Buying appropriate PPE for human force
	Coordination and cooperation	Coordinating with relief organizations
		Coordinating with firefighting units
		Cooperating with adjacent industrial units
		Establishing a memorandum of understanding with foreign organizations
		Cooperating with scientific research centers

Contd...

Table 2: Contd...

Category	Subcategory	Example of codes
	Training and awareness	Personne'l awareness on the area of responsibility and authority
		General and specialized training of personnel and managers
		Educating the methods of using PPE
		Holding maneuver and exercise plans
Safety culture	Inherently safe design	Safe design of petrochemical industries
		Safety interventions from construction to operation
		Safety-based site location
		Safe location of units within site
		Inherently safe equipment/systems
	Risk management	Risk identification and analysis
		Risk detection procedures
		Analysis of possible effects and defects
		Dynamic risk management of safety systems
	Monitoring and auditing	By-laws for monitoring emergencies and disasters
		Periodic evaluation and audit of preparedness programs
		Feedback-based and follow-up monitoring and assessment system
		Inspection of hardware systems
		Inspection of software systems
Sanction consequence	Hardware	Access to original parts
		High prime cost of parts
		Purchasing low-quality parts
		Spending long time to buy parts
		Product transportation equipment
	Software	Access to update software
		Utilization of new technologies
		Lack of access to world update knowledge
		Access to appropriate data
		Use of consequence simulation technology

ERP: Emergency response plan, PPE: Personal protective equipment

disaster impose in a short time, and should take preparedness for coping with fire seriously.."(P5).

Fire chain

Another critical element was related to the identification of chain reaction and process risks, and the industries must have the mechanism required for controlling spark sources. Furthermore, the participants strongly emphasized leak detection as the cause of many fires and initiator of major crises in the petrochemical industry.

"..The fires occurring in petrochemical are extensive, the type of which should be identified quickly. I myself was in Xpetrochemical company. It was a frightful scene and the industry assets were burning in a moment. Coping with the situation needs hardware and software preparedness.."(P2).

Policy-making

Regulations

The participants repeatedly pointed out that policy-making, as well as formulating governance and binding laws for preparedness programs with incentive and punitive systems can lead the industry managers towards preparedness components. The lack of regulatory by-laws in the safety and crisis fields for the petrochemical industries after its privatization can be addressed as an essential element.

"..There is no policy-making and law codification movement for the industry crisis in Iran, which is one of the gaps. Thus, several things happen spontaneously based on the experience because of lacking a law for binding managers".(P3)

Incident information documentation

The participants outlined an enhancement in preparedness during disasters by utilizing an incident- and crisis-recording system, and experiences (failure and success) and lessons learned. The preparation of the maps of petrochemical sites and diagrams of critical conditions, as another component, provides correct data for data mining in preparedness issues, which facilitates decision-making for the industry managers.

"..Rule formulation looks like a guide and roadmap. If the government enacts laws for industries so that they are obligated to meet the requirement for activity, manger follows. In this field, I have seen no macro policy-making and regulation, which clearly express what to do for preparedness against incidents so far..".(P7)

Incident insurance incentives

The presence of government incentive laws regarding incident and disaster preparedness issues for petrochemical industries, insurance coverage with discount, and tax waivers were among the incentives encouraging relevant mangers and contractors

to spend on the industry preparedness. According to the interviewees, the government incentives can be related to the recruitment of specialists and elite in the incident and disaster field in this industry, along with highlighting preparedness issues.

"..If the government decides for once to present macro incentive laws to Islamic parliament for offering discount and incentive to each industry having the elements, the industry manager certainly follows the issue. Indeed, cost-benefit is a win-win situation for the government and petrochemical companies.".(P11)

Management factors

Commitment and leadership

The industry manager must have a practical commitment to the industry preparedness in fire disasters. In fact, nothing happens unless a manager has commitment to the topics and puts them in management priorities. In addition, unit command and incident command chart based on the incident command system were suggested as a helpful element, upon which all of the chart members operate with unit terminology in the crisis scene.

"..This issue is not a priority for manager if he/she is not committed to it. The commitment of senior managers is one of the initial elements of each system and standard, which is useful".(P11)

Incident command system

Based on the interviews, the existence of the incident command system in the industries, and preparation and communication of job description to the personnel and officials involved in crisis could influence the preparedness. Further, the multiplicity of the officials making decision in crisis scene was addressed as a problem. Most of the interviewees introduced incident command as one of the essential factors for the industry preparedness, like air for human.

"..I saw with my own eyes in all of the crises, which I experienced that we did not know how to command on the scene. We must prepare a chart in advance and communicate with unit terminology. Confusion in operation, as well as the lack of prior planning were strongly felt in spite of having preparedness and possessing all things in 2016..".(P9)

Communication and information

Cohesive organizational communication should provide correct data for the personnel and managers involved in crisis over a proper time. Furthermore, information system inside and outside the site must be designed in a way which can communicate rapidly during incidents and disasters. The presence of coordination committees during incidents and disasters, and communication with adjacent industrial units, and relief and firefighting organizations played a critical role in enhancing the preparedness.

"...In fact, we observed the lack of communication and information during crisis. All individuals confused in scene. Consequently, the importance of communication is revealed. If we went there before crisis, we would communicate with neighbors and adjacent industrial units. Thus, they assisted us in the incident, while I felt the gap seriously..".(P17)

Planning

The interviewees declared the effectiveness of planning for preparedness against the worst possible scenario on the preparedness. The Emergency Response Plan (ERP) was detected as a key component and a roadmap for the industry preparedness. In addition, a monitoring and evaluation program should be designed to monitor the conducted activities.

"..Planning is the starting point. The industry should hire a planning manager who presents a program to all petrochemical units at the beginning of each year and expresses what the systems and programs to be followed for preparedness. Petrochemicals must possess ERP..".(P15)

Support factors

Equipment supply

Based on the individuals' perspectives, the petrochemical industries should prepare the eligible preparedness equipment and Personal Protective Equipment (PPE) specialized for operational teams and personnel. Further, fire-extinguishing equipment and alarm systems must be present in each unit due to the extent of the petrochemical industries. The industries should have software and hardware equipment for preparedness, and its managers must allocate a special budget through support unit.

"..Specialized fire-extinguishing equipment should be supplied for fire so that the industry cannot cope with the disaster until buying appropriate equipment. Most of our personnel are devoid of the minimum PPE..".(P8)

Coordination and cooperation

Considering the interviews, the intra- and extra-organizational coordination and cooperation, as well as establishing a memorandum of understanding with public and private relief organizations could greatly influence the preparedness promotion. Furthermore, the industries must collaborate with fire department and emergency unit. The cooperation with scientific research centers such as the universities and research institute meeting the scientific need of industries was one of the components for updating the industry knowledge. Indeed, communicating with the centers and establishing a memorandum of understanding in the preparedness program field can help industries.

"..Industries should hold a memorandum of understanding in the work, scientific, and technical fields. Universities are one of the places which can direct industry properly. The specialized meetings with fire department is another critical place for fire..".(P14)

Training and awareness

A majority of the participants referred to the importance of the general and specialized training of managers and personnel,

and maneuver. The personnel's awareness of their duties and authority during crisis was addressed as another effective element. The personnel should be informed about the topic through education, tabletop meetings, and maneuvering, the duties of whom must be prepared precisely and clearly.

"..Training, exercise, and maneuver are very important. This education should be continuous for manager or personnel. I believe that the industries must rear specialized firefighting teams since the materials used in the industries are flammable, and all should know the principles of fire and its extinguishment..".(P7)

Safety culture

Inherently safe design

The initial and inherently safe design of the industries from the design phase to the operation one was determined as an effective factor in the preparedness. The participants believed that the consideration of safety interventions since construction to operation facilitates the next actions. The safe location of petrochemical sites using software such as geographical information system and satellite images was beneficial, which results in locating and designing units within the site safely, along with its overall safe location. In addition, safe equipment and systems should be bought for the petrochemical industries against fire incidents and disasters.

"Prioritizing safety since the zero phase and design of project is the most essential issue for preparedness. The design should be safe inherently and safe equipment must be purchased for industries..".(P17)

Risk management

Based on the interviews, analyzing possible effects and defects could influence the preparedness. The results suggested the effectiveness of the codification of risk detection procedures and dynamic risk management of safety systems in industries on the preparedness. The identification and evaluation of petrochemical industry risks can facilitate the decision-making for the acceptableness or unacceptableness of the existing risks and propose the required corrective and control actions.

"..Risk management and identification are critical in the petrochemical and process industries. We call them the heart of the system. Risk management includes risk detection and evaluation, and finally its assessment, which should be continuously performed by specialist and specific team".(P19)

Monitoring and auditing

The individuals reported as increase in the preparedness by deploying feedback-based monitoring and assessment system, and inspecting hardware and software systems regularly, leading to the effective response of the industries during fire. The monitoring and auditing instructions and checklists can accommodate the current situation with the standard. In the case of noncompliance, corrective approaches and programs can be suggested to enhance the industry preparedness.

"..In the petrochemical industries, monitoring and audit is important, and daily, weekly, and monthly checklists are applied. Something may occur every day if systems are not inspected..".(P18)

Sanction consequence

Hardware

The results demonstrated the effectiveness of sanction on access to main petrochemical parts, which deprives the industry producers of high-quality and first-class parts. Regarding the hardware consequences of sanction, most interviewees addressed that the sanction of Iran's industries influenced the access to needed equipment and parts, equipment prime cost, time spent for buying, as well as purchasing high-quality parts. Furthermore, some declared the great effect of sanctions on product transportation equipment. Thus, the bought parts are devoid of necessary standards and the industries have a limited choice of goods in the global market.

"..We are under sanction conditions. Thus, we cannot purchase the required parts or are forced to buy low-quality ones. Given that the parts are received in a long process, the industry may experience any incident or close the unit before receiving the part..".(P20)

Software

Based on the interviews, software sanction affected the access to update software and new technologies in the industry, which results in failing to access to appropriate and update data. Along with lacking access to world update knowledge, the failure to use the fire consequence simulation technologies was among the sanctions.

"..They have deprived us of update software and technologies. The industries can hardly purchase update software. Sometimes, they provide the software, while we cannot pay them..".(P19)

Discussion

Based on the results, fire characteristics, regulation codification, incident information documentation, planning, incident command, training and awareness, risk management, safety culture, and software and hardware sanctions were extracted as the main components.

The fire characteristic in terms of destruction extent and damage to individuals and environment was detected as one of the effective elements on the preparedness. Some researchers reported that the incidence of fire in a petrochemical complex resulted in releasing hydrocarbon inside the complex and up to the radius of 10 km and exposing above 61,000 residents in the region.[18] According to Cozzani *et al*.,[19] chain reaction during fire incidents in the industries leads to catastrophe for adjacent industries. For example, 11 tanks were exploded and 12 ones died following the reactions in the fire of Lanzhou petrochemical company (China).[5] Fire chain reactions can have catastrophic consequences on individuals, environment,

and economy.[20] It seems that the identification of fire characteristics, as well as familiarity with fire consequences, can be effective in promoting the preparedness of the personnel and managers of the petrochemical industries in responding to the incidents.

Regulations, as well as defining incident insurance incentive packages affects the preparedness of petrochemical complex industries in fire.[21] The United States Congress developed rules for decreasing the probability and consequences of catastrophic chemical incidents after occurring chemical incident in Bhopal, India, and some major ones in the USA.[22] In this regard, National Disaster Management Authority recommended national guidelines to manage disasters in chemical incidents for making capacity, managing risk and information, and coordinating actions to enhance preparedness at different levels.[23] Accordingly, the enforcement of proper legislation and proper policy-making of the government plays a significant role in the petrochemical industry preparedness during incidents and disasters.

Regarding management factors, as another effective component, the results suggested that the preparedness involved the utilization of different management instruments. Consequently, the respondents to probable disasters can intervene better by planning.[24] In addition, the management can improve workers' commitment to safety, as well as performing safe behaviors in workplace.[25] The participants referred to the ability of incident command system to assist in preparedness and disaster effect reduction.[26] The results indicated the importance of information as an emergency element in the industries for evaluation, as well as the quick response of those outside the facilities.[27] Due to the importance of the above-mentioned issues, it is recommended that petrochemical industry managers be committed to the programs and strategies for preparedness against disasters.

Further, support factor was determined as the other critical element for the preparedness, addressing the ability of the industry to supply the preparedness parts. Thus, the petrochemical industries should have adequate financial sources to prepare the goods of preparedness programs at the best time and quality. In fact, the higher preparedness of industry for emergency conditions results in managing decision-making in the crisis conditions better.[28] Training specialized personnel, and expanding their knowledge and skill are considered as the necessities of human logistic, as well as preparedness factors. Furthermore, maneuvers and exercise are among the efficient and common instruments in the disaster preparedness phase. This type of exercise is widely used in planning, educating, and exchanging knowledge during emergency conditions.[29] The International Organization for Standardization (ISO) and American National Standards Institute released ISO 22398:2013 guidelines for the standard formulation of the patterns and methods required for planning and executing preparedness exercises,[30] which can play a key role in the petrochemical industry preparedness during disasters.

In addition, the results introduced risk management as another important component in the preparedness. In this respect, the interviewees outlined the valuableness of real-time risk management for activating incident prevention and control strategies.[31] Based on the results of the previous studies, different interventions, such as risk assessment and control actions are applied to decline the probability of emergency conditions and diminish their consequences.[32] The results of a study in Iran revealed the lack of a comprehensive program for examining and managing incidents and disasters.[33] Accordingly, risk management is an essential element. It is expected that petrochemical industry managers evaluate the risks existing in the complexes continuously, along with the other factors.

Further, the individuals declared that sanction, as well as the lack of access to high-quality parts, was among the preparedness components. They emphasized that sanctions imposed additional costs on companies and industries in terms of acquiring technical knowledge.[34] Sanction affected access to parts, access time, and prime cost, and disrupted production, export, investment, and economy in the sectors.[35] Seemingly, the attempt to lift industry sanctions can lead to the higher preparedness of the industries and complexes in Iran during disasters. Finally, future studies are proposed to specify the elements of the petrochemical industry preparedness in the other emergency conditions and natural and human-made disasters.

Strengthens and limitations

In the present qualitative study, the experiences of HSE senior managers and crisis managers in the petrochemical industries were used with a qualitative method to detect the factors of petrochemical industry preparedness in the postdisaster fires in Iran for the first time. Executive restrictions on participation and difficulty of access to the participants for interview due to COVID-19 protocols were among the limitations of this study, which is ascribed to the selection of the individuals having scientific knowledge or adequate experience in the preparedness.

Conclusions

The results of the present study represented the effectiveness of several components on the petrochemical industry preparedness in postdisaster fires. The industries are recommended to implement the factors for promoting its preparedness against postdisaster fires. An enhancement in the preparedness can result in decreasing disaster consequences. Therefore, policy-makers and managers can use the results of this study to plan the programs and strategies for promoting the petrochemical industry preparedness during postdisaster fire. The petrochemical industries can identify and improve the elements influencing the preparedness of their organization using the results.

Ethics approval and consent to participate

This study was derived from a PhD dissertation approved by Shahid Beheshti University of Medical Sciences with the ethics code of IR. SBMU. PHNS. REC.1399.109. The written and verbal informed consent for interviewing and recording was first gained from all of the participants to observe ethical considerations.

Availability of data and material

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Authors' contribution

Concept and design of the study: DP, DKZ, and ZGH. Data collection in the field: DP. Data transcription and coding: DP, DKZ, and ZGH. Data analysis: DP, DKZ, ZGH, and AE. Writing an original draft and editing of the manuscript: DP. Critical revision of the manuscript: DKZ, ZGH, RGH, and NJ. All authors have read and approved the manuscript.

Acknowledgment

Authors thank all the participants for sharing their valuable experiences and knowledge.

Financial support and sponsorship

This study was financially supported by Shahid Beheshti University of Medical Sciences, Tehran, Iran.

Conflicts of interest

There are no conflicts of interest.

References

1. Malmasi s, Jozi sa, Monavari sm, Jafarian Moghadam e. Environmental Impacts of PET- PTA Petrochemical Industries (Case Study: Mahshahr Economic Special Zone). Human & Environment 2010;8:73-81.
2. Shaluf IM, Ahmadun FR, Said AM. Fire incident at a refinery in West Malaysia: The causes and lessons learned. J Loss Prev Process Ind 2003;16:297-303.
3. M. S. Mannan, Lees' Loss Prevention in the Process Industries: Hazard Identification, Assessment and Control, Elsevier Butterworth-Heinemann, Amsterdam, NL, 4th edn, 2012.
4. Nivolianitou Z, Konstandinidou M, Michalis C. Statistical analysis of major accidents in petrochemical industry notified to the major accident reporting system (MARS). J Hazard Mater 2006;137:1-7.
5. Liu X, Zhang Q, Xu XJ. Petrochemical plant multi-objective and multi-stage fire emergency management technology system based on the fire risk prediction. Procedia Engineering 2013;62:1104-11.
6. Safoura K, Mostafa Mirzaei A, Iraj M. Human errors assessment for board man in a control room of petrochemical industrial companies using the extended CREAM. J Health Field 2018;6:28.
7. Omidvar M, Mazlomi A, MohammadFam I, Rahimi Foroushani A, Nirumand F. Development of a framework for assessing organizational performance based on resilience engineering and using fuzzy AHP method: A case study of petrochemical plant. JHSW 2016;6:43-58.
8. Abbassinia M, Kalatpour O, Soltanian AR, Mohammadfam I, Ganjipour M. Determination and score of effective criteria to prioritize emergency situations in a petrochemical industry. Occup Hygene Health Promot J 2019;3:16-25.
9. Saloua B, Mounira R, Salah MM. Fire and explosion risks in petrochemical plant: Assessment, modeling and consequences analysis. J Fail Anal Prev 2019;19:903-16.
10. Naderi M, Mohammadfam I, Kalatpour O. Determining training needs of emergency response team's using task criticality analysis at Bouali Sina Petrochemical Co. And comparison with the HAZWOPER standard. Iran Occup Health 2020;17:233-43.
11. Mortazavi S, Parsarad M, Mahabadi HA, Khavanin A. Evaluation of chlorine dispersion from storage unit in a petrochemical complex to providing an emergency response program. Iran Occup Health 2011;8:68-77.
12. Rebeeh Y, Pokharel S, Abdella GM, Hammuda A. A framework based on location hazard index for optimizing operational performance of emergency response strategies: The case of petrochemical industrial cities. Saf Sci 2019;117:33-42.
13. Einarsson S, Rausand MJ. An approach to vulnerability analysis of complex industrial systems. Risk analysis 1998;18:535-46.
14. Girgin S. The natech events during the 17 August 1999 Kocaeli earthquake: Aftermath and lessons learned. Nat Hazards Earth Syst Sci 2011;11:1129-40.
15. Tenny S, Brannan JM, Brannan GD. Qualitative Study. In: StatPearls. Treasure Island (FL): StatPearls Publishing Copyright © 2022, StatPearls Publishing LLC; 2022.
16. Graneheim UH, Lundman B. Qualitative content analysis in nursing research: Concepts, procedures and measures to achieve trustworthiness. Nurse Educ Today 2004;24:105-12.
17. Lincoln YS, Guba EG. But is it rigorous? Trustworthiness and authenticity in naturalistic evaluation. New Dir Program Eval 1986;1986:73-84.
18. Shie RH, Chan CC. Tracking hazardous air pollutants from a refinery fire by applying on-line and off-line air monitoring and back trajectory modeling. J Hazard Mater 2013;261:72-82.
19. Cozzani V, Gubinelli G, Salzano E. Escalation thresholds in the assessment of domino accidental events. J Hazard Mater 2006;129:1-21.
20. Kadri F, Châtelet E, Chen G. Method for quantitative assessment of the domino effect in industrial sites. Process Saf Environ Prot 2013;91:452-62.
21. Salehi V, Zarei H, Shirali GA, Hajizadeh K. An entropy-based TOPSIS approach for analyzing and assessing crisis management systems in petrochemical industries. J Loss Prev Process Ind 2020;67:104241.
22. Belke JC. Chemical accident risks in US industry – A preliminary analysis of accident risk data from US hazardous chemical facilities. Loss Prevention and Safety Promotion in the Process Industries. Elsevier; 2001. p. 1275-314.
23. Gupta AK, Nair SS. Chemical (Industrial) Disaster Management, Trainer's Module. New Delhi: National Institute of Disaster Management(Ministry of Home Affairs) 2012. p. 20. Available at: https://www. nidm.gov.in.
24. Xue Y, Fan Y, Xie X. Relation between senior managers' safety leadership and safety behavior in the Chinese petrochemical industry. J Loss Prev Process Ind 2020;65:104142.
25. Zahiri Harsini A, Ghofranipour F, Sanaeinasab H, Amin Shokravi F, Bohle P, Matthews LR. Factors associated with unsafe work behaviours in an Iranian petrochemical company: Perspectives of workers, supervisors, and safety managers. BMC Public Health 2020;20:1192.
26. Kestenbaum R. Incident Command System Experience and Training in the Midstream and Downstream Oil and Gas Sector: California State University, Long Beach; 2019.
27. Tim Perkins K, editor. An Integrated Approach to Corporate Preparedness. 2005 International Oil Spill Conference, IOSC 2005; 2005.
28. Rahimi E, Javanmard H, Portabatabaei SA. Designing a strategic model for crisis management in a petrochemical industry. Strateg Manag Res 2017;23:99-114.
29. Fowkes V, Blossom HJ, Sandrock C, Mitchell B, Brandstein K. Exercises in emergency preparedness for health professionals in community clinics. J Community Health 2010;35:512-8.
30. Farhadi S, Mohammadfam I, Kalatpour O. Introducing a pattern for developing emergency scenarios in industries and studying the conformity of the exercised scenarios in the process industries with the presented pattern %. J Iran Occup Health J 2017;14:72-81.
31. Yang M, Khan F, Amyotte PJ, Protection E. Operational risk assessment: A case of the Bhopal disaster. Process Safety and Environmental Protection 2015;97:70-9.
32. Mohammadfam I, Bastani S, Golmohamadi R, Saei A, Es-Haghi MJ. Applying social network analysis to evaluate preparedness through

coordination and trust in emergency management. Environmental Hazards 2015;14:329-40.
33. Khankeh HR, Khorasani-Zavareh D, Johanson E, Mohammadi R, Ahmadi F, Mohammadi R. Disaster health-related challenges and requirements: A grounded theory study in Iran. Prehosp Disaster Med 2011;26:151-8.
34. Majidpour M. The unintended consequences of US-led sanctions on Iranian industries. Iran Stud 2013;46:1-15.
35. Ahmadi A. The impact of economic sanctions and the JCPOA on energy sector of Iran. Glob Trade Customs J 2018;13:198-223.