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Release of toxic substances in disasters of oil, gas, and petrochemical units

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1. Introduction

Toxic materials released from oil, gas, and petrochemical units, agrochemical pollution, asbestos dust, and aerosolized radionuclides might not be hazards that immediately come to mind when considering the types of damage associated with a natural disaster [1,2]. When hazardous materials are released during extreme natural events (such as volcanic eruptions, earthquakes, landslides, hurricanes, tornadoes, and blizzards), humans are at an increased risk of being exposed to hazardous materials or secondary hazards like fires or explosions that are caused by the ignition of flammable materials [3].

Increased instances of community contamination by hazardous or toxic materials in recent decades are intrinsically linked to industrial disasters, careless corporate disposal of toxic wastes, and poorly planned home projects in hazardous environments. The total number of technical and natural catastrophes has climbed significantly from the 1990s to 2006, according to the 2007 World Disaster Report (International Federation of Red Cross and Red Crescent Societies, 2007). Communities' "toxic exposure" has been compared by Edelstein (1988) to a modern disease with long-lasting effects [4]. He created the phrase "contaminated community," which refers to any residential area or human settlement situated inside or close to the boundaries of exposure to a known environmental hazard [5].

The two main sources of community contamination are hazardous waste dumps and unintentional discharges of harmful chemical substances. According to the Agency for Toxic Substances and Disease Registry (ATSDR), the cost of just four

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childhood health conditions—asthma, lead toxicity, cancer, and developmental disabilities—associated with hazardous chemical exposure in the community exceeds 54 billion dollars annually. The majority of toxic disasters have human or technical causes. A hazardous contamination event disturbs the natural balance as well as the social relationships. A toxic community generally developed as the dispute between the disaster's perpetrator and its victims grew more heated [6]. Toxic waste is sometimes referred to as the disease of the 20th and 21st centuries, which is a metaphor that fits the expanding number of damaged towns worldwide rather well.

This chapter aims to discuss systematic and industrial disasters that release hazardous and toxic wastes into the biophysical and built environments culminating in the contamination of communities and the subsequent adverse health consequences among the exposed populations and to discuss variables that could affect the disaster mitigation efforts of oil and gas projects.

2. Overview of oil and gas disasters

The global economy's development depends largely on the oil and gas industry [7]. In contrast, petrochemicals are taken from the surface of the land and deep seawater through the use of oil and gas drilling activities [8]. For oil and gas drilling teams, this operation is significantly linked to risk factors that pose a life-threatening threat. Due to a lack of health and safety laws and prevention strategies, hundreds of accidents and fatalities have been reported at onshore and offshore drilling sites throughout the years [9,10]. However, only a small percentage of risk variables have been under control in recent years due to the unpredictable character of the drilling industry [11].

The oil and gas drilling and production industries account for hundreds of fatalities and tens of thousands of injuries each year [12]. Since many chemicals are unexpected and dangerous, there have been numerous reports of safety, environmental, and ergonomic risks worldwide [11,12]. While several fatalities and serious injuries have been reported during drilling and maintenance activities worldwide, both onshore and offshore. Large-scale deserters have occurred over a period of 17 years for a variety of reasons [13]. In Table 9.1, the number of fatalities and injuries among the drilling crew during the previous 18 years is highlighted along with an in-depth analysis of drilling and production disasters involving oil and gas. Table 9.1 [8,10,12–17] indicates that the majority of oil and gas release accidents and disasters

Table 9.1 An overview of disasters related to oil, gas, and petrochemical units [2–7].

Year	Country	Operator	Reason investigated
2002	Saudi Arabia	Saudi Aramco	Blowing up
2004	Egypt	Petrobel	Out of control
2005	Mumbai High, Indian Ocean	Oil and Natural Gas Corporation (ONGC)	An explosion of fire
2006	United States of America	Raleigh	Explosion
2007	Saudi Arabia	Saudi Aramco	Fire during pipeline maintenance
2009	Australian	Montara Production Platform	Blowout of the Montara oil well
2010	Russia	Gazprom	As a result of the fire, the helicopter crashed
2012	Nigerian Delta Region	Chevron	Explosion
2012	Malaysia	PETRONAS	Fire explosion
2012	Malaysia	PETRONAS	Fire explosion
2013	Saudi Arabia	Saudi Aramco	Sank maintenance platform
2014	Malaysia	Sapura Kencana	Dropped from eight
2015	Azerbaijan	SOCIAL	Fire explosion due to leakage
2016	Gulf of Mexico	Whistler Energy II LLC	Drop items
2017	Pakistan	Shell	Fire explosion
2018	Malaysia	PETRONAS	Drill engine fire explosion
2019	New Mexico, United States of America	Exxon Mobil(XOM.N)	A pump jack
2022	Alabama. United States of America	Southern Natural Gas	Pipeline accident

occur during drilling in Middle Eastern and Southeast Asian nations due to the diversity of the environment, a lack of effective resources for both drilling domains for accident prevention, and insufficient industrial safety and health protocols.

In the oil and gas sector, there have been numerous incidents that have resulted in numerous fatalities, substantial financial loss, and/or significant environmental damage [4]. Major factors that contribute to an accident's occurrence include things like natural causes, insufficient training, material, structural, and mechanical failures and malfunctions [5]. Employees can sustain injuries from falling objects, slips and falls, and chemical exposure [6–8].

Various oil, gas, and petrochemical disasters are illustrated in recent studies. In August 2009, the Montara production platform accident occurred in Australian waters without causing any fatalities. Due to the failure of concrete and cement at the Montara oil well, a major oil spill and fire occurred. There had been no installation of a blowout preventer. Abridged to the Montara platform by a bridge, the West Atlas drilling rig burned down completely and was demolished. As a result of the complicated arrangements between regional and national authorities, the Montara accident caused significant problems. Oil and gas offshore regulations in Australia were changed as a result of this accident [18].

Furthermore, there are multiple causes for significant incidents, some of which are latent, and each of which contributes to the sequence of incident escalation [19], hence, there main causes of oil and gas accidents, Failure of the control system, including a lack of effective control and maintenance issues with safety-sensitive equipment [20], Procedural failures [21], Human factors [22], Severe Weather [23], Mechanical failures [24], Escape, evacuation, and rescue failures [25], Design flaws [26], Ecotoxicity [27], Earthquake [28], Soil pollution [29], Social disruption [30], Chemical exposure [31].

3. Categorization of oil and gas hazards

Due to the intricate and potentially fatal operations and occurrences, oil and gas disasters are always seen to be among the most difficult and dangerous [11,16]. While both onshore and offshore oil and gas drilling operations have some potential risks [14,32]. As shown in Fig. 9.1, most of them can be divided into four main categories: physical, chemical, ergonomic, and environmental dangers.

(i) Physical hazards

One of the most prevalent and regular working risks in practically every industrial setting is common hazards. One of the most frequent hazard categories in onshore and offshore drilling operations for oil and gas exploration is safety hazards [33]. Additionally, the following risks were listed by safety and health specialists as being present during oil and gas drilling activities: slipping and falling, falling from a height, dropping an object, getting stuck by equipment, being electrocuted, and being in a confined space [33,34].

(ii) Chemical hazards

Many injuries and fatal burns are reported each year as a result of the improper handling of hazardous drilling fluids during the oil and gas drilling process [34]. A variety of drilling fluids and chemical-based muds must be handled by drilling crews

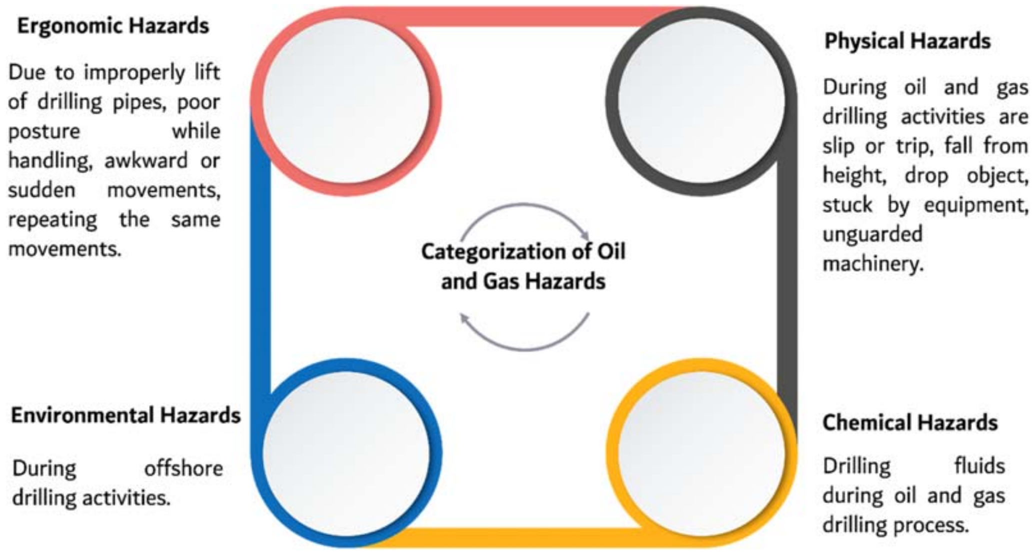

Figure 9.1 Oil and gas hazards categorization.

throughout the oil and gas exploration process, which translates into chemical dangers. Furthermore, chemical hazards are posed by the interaction of dangerous drilling fluids with natural radioactive materials (NORM), fires, and exposure to lethal gases such as hydrogen sulfide (H_2S) [15,35].

(iii) Ergonomic hazards

Inside petrochemical units, the oil and gas drilling process is strongly linked to ergonomic risks [15,36]. While most of the lifting and handling tasks are now carried out using sophisticated technology or cranes, the rate of ergonomic injuries is still rising as a result of poor handling and lifting techniques. While the inappropriate lifting of drilling pipes, poor handling posture, clumsy or abrupt motions, repetition of the same movements, and using excessive force during activities have all been linked to ergonomic hazards at onshore and offshore drilling sites [37].

(iv) Environmental hazards

One of the main issues facing the global upstream oil and gas sectors is environmental hazard [17]. However, compared to onshore drilling, the rate of accidents caused by environmental concerns was substantially reported. Additionally, during offshore drilling operations, these environmental dangers have impacted maritime and helicopter operations. A significant worry that might be exceedingly dangerous for the maritime environment and offshore environment is the frequent oil spills that occur during the drilling and production processes [38].

One of the main causes of water pollution, which results in severe environmental harm and economic devastation, is marine oil spills. They significantly reduce aquatic biodiversity by disrupting the biological balance of the seas and other bodies of water [39]. Numerous policy concerns surrounding the secure transportation of oil volumes are brought up by the potential of oil leaks. For the preservation of the marine environment and life, effective cleanup of these spills is a must. To reduce the negative effects on the environment and human health, onshore and offshore oil response measures must be implemented at the spill site together with continuous monitoring systems.

4. Release of toxic substances from oil and gas accidents

Toxic or hazardous material is dangerous to the environment or increases the risk of injury, death, or serious illness because of its chemical, physical, or infectious characteristics. The toxicity and concentration of a substance, as well as its quantity and concentration, all play a significant role in its danger [3].

During oil, gas, and petrochemical disasters, many types of toxic materials are released [40]. Sulfur Dioxide (SO_2), Hydrogen Sulfide (H_2S), and Ammonia (NH_3) are some of these substances [40]. However, H_2S is a health hazard and a corrosion catalyst. Sulfur is recovered from it and used to manufacture sulfuric acid, medicines, fertilizers, cosmetics, and rubber products. There is a major concern at this stage about the possibility of leaks that could negatively impact both humans and the environment. Besides causing leaks, leaks also cause pipelines to be taken out of service to be repaired. Many factors can cause leaks, such as earthquake-induced deformation, corrosion, wear and tear, material flaws, and even intentional damage [40].

A flammable, extremely toxic gas, hydrogen sulfide is colorless and lighter than air. It is soluble in water and is extremely toxic. At concentrations well below its very low exposure limit, it emits an odor that is similar to that of rotten eggs. Hydrogen sulfide causes irritation, dizziness, and headaches when exposed at low levels, depression, and eventually death when exposed at levels that exceed the prescribed limits [41]. H_2S also negatively impacts the ecological system in addition to harming human beings. As an example, H_2S in water may cause a change in PH value, resulting in ecological imbalances between microbes and aquatic species.

To manage and control toxic and hazardous wastes in an environment that protects both human health and the environment, it is crucial to identify and classify waste accurately. Hazardous waste has been categorized several times over the years. Toxic waste is typically a part of hazardous waste [42]. As a basic grouping method, wastes can be categorized according to their risk to humans and the environment. Thus, wastes are divided into three risk categories: high-, intermediate-, and low-risk; some examples are shown in Table 9.2.

Numerous studies have found that the drilling for and extraction of oil and gas expose workers to numerous harmful substances and environmental risks [49,50]. When an offshore facility or its people are attacked by fire or explosion, they can suffer immediate damage (oil rigs and installed equipment can be destroyed or damaged, while staff members may be injured or killed) [51]. Hydrocarbon releases can permanently damage the environment, including wildlife and people around the area that is directly affected by these oil and gas disasters [18,52]. According to this logic, the greatest risks include:

(i) Fires and explosions can result from hydrocarbon releases (gases or liquid drops dispersed in clouds can ignite when they contact the air).

(ii) Sea surface and underwater oil spills.

The oil and gas industry has experienced several accidents resulting in many deaths, property losses, and environmental damage [53]. Accidents can be caused by a variety of factors

Table 9.2 Risk categories of oil and gas toxic materials.

Risk categories	Properties	Examples	References
High	Extremely toxic, bio-accumulative, migratory, and harmful substances.	Solvents containing chlorides, persistent organic pollutants (POPs), wastes containing heavy metals including lead and cyanide, and wastes containing polychlorinated biphenyls (PCBs).	[43,44]
Intermediate	Wastes have poor mobility and are largely insoluble.	Sludges containing metal hydroxide.	[45–47]
Low	Wastes typically consist of large quantities of foul-smelling, harmless wastes.	Municipal solid wastes.	[48]

including defects in materials, structures, and mechanical parts, malfunctions, human errors, and natural disasters [54]. An injury to employees can result from an object being thrown at them, slipping and falling, or being exposed to chemicals [55].

There are three types of releases of hazardous materials from oil, gas, and petrochemical units through disasters:

1. An incidental release that can be dealt with using readily available and readily available items that are readily available, spill kits, or spill guns. At the job site, employees in the vicinity manage accidental discharges. The near surrounding is a visual field in which the employee is physically present.
2. Operations Level Releases are releases that need special personal protective equipment to clear up, specific materials or equipment, or spills that surpass the capacity of the department's cleaning employees. Employees in the vicinity can safely handle spills and releases at the operations level with the right PPE and training. These spills may be rather enormous, but they are not life-threatening, and they need to be contained with the use of specialized equipment that isn't often kept in the unit.
3. Dangerous Substances (Technician Level) Releases are accidents that demand a Disaster Response team to respond and use active control methods to prevent the leak of a dangerous substance. By caulking, patching, or otherwise fixing a leak, the team may be able to stop the flow of materials. Examples of emergency disaster team responses include a spilling oil tank and a polychlorinated biphenyl (PCB) oil line on electrical equipment.

5. Oil and gas disaster risk mitigation

There are several risks associated with oil and gas projects: massive capital investments, the involvement of numerous parties, complex technology, and significant environmental and social consequences [56]. The impacts of disasters can be minimized if a disaster management strategy is adopted. The possibility of disasters is unavoidable, and they can happen at any time. Disasters can be prevented by mitigating risks from the start. The assessment of disaster risk should be integrated with risk analysis [57].

The impacts of disasters can be minimized by implementing a strategy to deal with them. Disasters can occur at any time and cannot be prevented [58]. There is always the possibility of an uncertain, unexpected, and even undesirable event affecting the prospects of a particular investment [2]. In the oil and gas industry, there have always been social conflicts and casualties because of gas leaks [3]. Many parameters in the industrial system can contribute to the occurrence of risks and hazards in the oil and gas sector [4].

The disaster risk assessment must therefore incorporate any risk analysis. Project life cycles have inherent risks that must be identified to develop an effective framework for assessing risks. Additionally, constructors should give priority to the concept of sustainable development in their activities as a means of addressing social, environmental, and economic challenges in the construction sector [59].

To achieve sustainable development, the top oil and gas companies today are required to have implemented risk management and adhered to ISO 31000:2009 as a framework. A framework like this can be used to integrate various management processes, such as the management of health, safety, and environmental risks [60]. Even so, the continued actions continue to have harmful effects on the environment. Furthermore, modern international oil and gas corporations place a greater emphasis on preventive measures than coping mechanisms, indicating that sustainable development has not been fully integrated into risk management applications [31].

For construction projects, risks must be managed by the Sustainable Development Goals, which include goals aimed at improving sustainability and eradicating poverty. Efforts to reduce poverty must be combined with progressive economic growth so that all risks that could harm the economy can be managed. This includes risks related to disasters and vulnerabilities in the development plan [61].

It is imperative to understand risk management so that sustainable development goals can be achieved. Researchers have explored the issue using different approaches. As a result of the AHP (analytic hierarchy process) approach, researchers [27,62,63] developed the concept of risk management, which is a decision-support system that can be used to determine maintenance options for oil and gas pipelines so that the pipeline project can survive while taking into account the pipes' quality and the environment [63].

Several risk-reduction measures were adopted before risk mitigation in the oil, gas industry, and petrochemical units. Numerous studies cited disasters as having contributed to the prevention of releases. Many of these are recommended for use in the catastrophe mitigation process because they are accepted business practices. Fig. 9.2 illustrates these actions [64].

Additionally, it was noted that a significant proportion of incidents in the oil and gas sector are linked to movable structures. All of the events that have been looked into have served as stark reminders to the oil and gas sector that risk management and uncertainty reduction need to be continually improved if safe operations are to be ensured as well as the danger of accidents, significant accidents, and disasters is reduced. In the oil and gas business, however, proactive learning and the creation of a dynamic risk culture are required to supplement reactive learning following significant accidents and disasters [65].

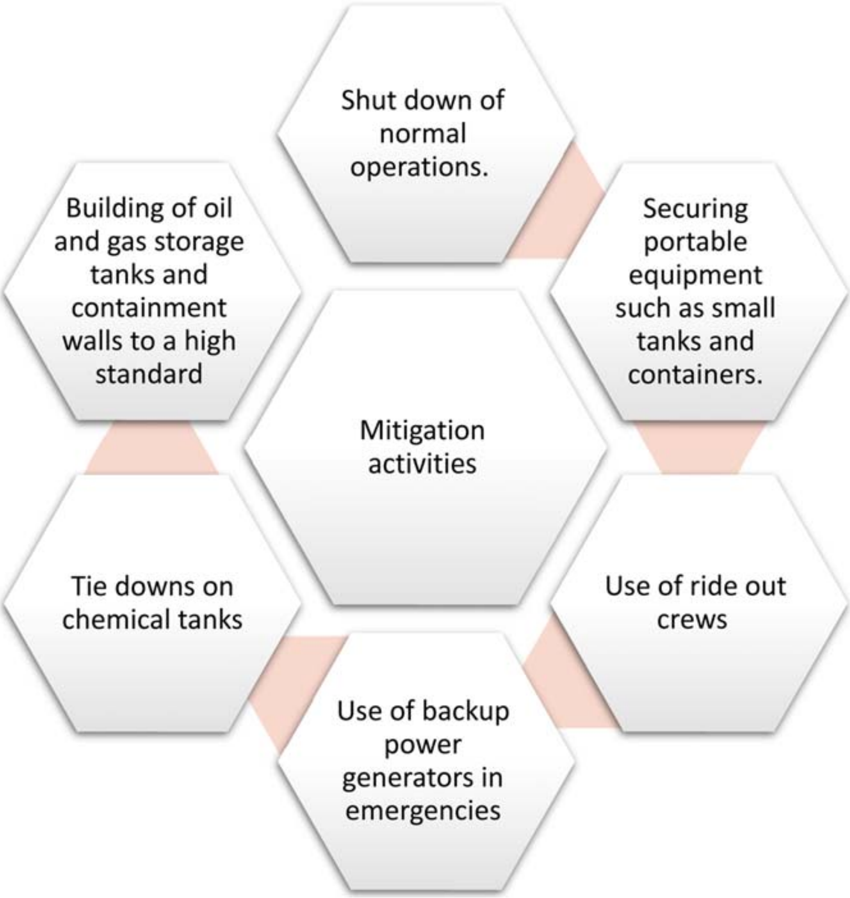

Figure 9.2 Mitigation activities during the oil and gas disasters.

6. Conclusions and future outlooks

Disasters at petrochemical, oil, and gas facilities are thought to be the leading cause of the release of harmful compounds into the environment. Furthermore, they are thought to be more dangerous than accidents in the construction sector and twice as risky as accidents in other sectors of the economy. According to the overall conclusion of this chapter, it has been specified that the categories of toxic materials released from the oil and gas industry have been divided into three levels: high-, intermediate-, and low-risk categories. Additionally, it has been revealed more than 12 main causes of oil and gas accidents as well as risk reduction techniques to lessen the toxicity of petrochemical materials released during oil and gas disasters.

Therefore, oil, gas, and petrochemical units and risk management teams must develop risk plans in the industrial areas for oil, gas, and petrochemical units to be aware of any types of risks and be aware of the nature of released materials to deal with them carefully and to reduce their potential risks.

We recommend conducting different research studies on the types of disasters and the nature of hazardous materials that could pose a real danger to humans and the environment, and research studies about environmentally friendly equipment that can be used to address risks.

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