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THE IMPACT OF PHYSICAL, CHEMICAL AND BIOLOGICAL HAZARDS ON OCCUPATIONAL ACCIDENTS AND ILLNESSES IN THE OIL AND GAS INDUSTRY – A REVIEW

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Abstract: As industrialisation spreads around the globe, occupational safety and health hazards are increasing. Recognising hazards is crucial for proper prevention and control to protect workers' health and well-being. For an organisation its personnel are its most precious asset; thus, the management should prioritise their health and well-being. Physical, chemical, and biological health hazards are the three categories used to classify Occupational Safety and Health (OSH) risks that may lead to the emergence of accidents, diseases, and illnesses. Industrial organisations, including the oil and gas sector may be linked to occupational safety and health risks. Oil and gas operations involve various activities, including exploration and drilling, conventional oil and gas production, extraction and processing of tar sands, heavy oil processing, and pipeline operations. Operations in this industry for offshore and onshore sites involve numerous risks, including hazardous chemicals and the complex, critical equipment in the plant. The oil and gas industry can be characterised as having non-zero risk and non-free hazards. This review is intended to determine the effects of physical, chemical, and biological hazards on occupational accidents and illnesses in the oil and gas industries and the resultant implications upon OSH management.

Keywords: Occupational safety and health, physical hazard, chemical hazard, biological hazard, oil and gas.

Introduction

The oil and natural gas industries are pivotal in the global energy sector, significantly influencing the world economy. Oil and gas production and distribution processes are complex, capital-intensive, and reliant on advanced technology. Historically, natural gas was often found in conjunction with oil, particularly in the upstream or production phase of the industry (Fidancı & Ozturk, 2015). For much of the industry's history, natural gas was viewed as a by-product and frequently found in large quantities in various regions worldwide. However, it is noteworthy that natural gas produces lower greenhouse gas emissions than oil and coal (Zhao *et al.*, 2015; Tong *et al.*, 2020; Wang *et al.*, 2020; Wang *et al.*, 2021).

The oil and gas industry is segmented into three main sectors: Upstream, midstream, and downstream. These sectors align with three primary categories of activities within the oil and gas industry's value chain.

These three sectors represent the chronological sequence of essential activities in the oil and gas industry. Downstream activities involve refining and marketing oil and gas while midstream activities focus on transporting and storing these resources. Upstream activities are concerned with the exploration and production of oil and gas (Ezejiofor *et al.*, 2013; Wei *et al.*, 2015; Wang *et al.*, 2020; Wang *et al.*, 2021; Zhang *et al.*, 2021). In addition to standard industrial hazards, personnel in the oil and gas industry face unique occupational risks. These include handling combustible or toxic materials and the dangers of travel to offshore installations. Moreover, the machinery, equipment, and hazardous conditions in this sector pose significant threats, potentially causing severe injuries or endangering lives (Nwankwo, 2020).

Manufacturing encompasses many industries, including textiles, food and beverages, leather, plastics, heavy equipment, chemicals, electronics, and others (Guo *et al.*, 2016). It employs a diverse workforce across its various sub-industries, including seasonal and young workers. Occupational Safety and Health (OSH) hazards in this sector often include uncomfortable working conditions and manual handling (OSHA, 2011). Specifically, employees are exposed to various risk factors in the oil and gas industry such as chemical, physical, and biological hazards (Tang *et al.*, 2018). Consequently, it is vital to monitor their working conditions and overall well-being continuously. Health protocols should be established, and periodic medical check-ups are recommended for each worker. These check-ups should be tailored to the specific type of job and work area to identify any deviations from normal health early and to determine the necessary preventative measures.

The oil and gas industry is inherently associated with a higher risk of occupational illnesses and accidents. Challenges and uncertainties related to OSH are persistent throughout its various operations (Zhao *et al.*, 2015; Li *et al.*, 2018; Zhang *et al.*, 2021). Annually, hundreds of fatalities and thousands of injuries are reported in this sector. Often, these incidents are attributed to the negligence of safety and health regulations and the ineffective implementation of emergency action plans. Such plans are significant for fire explosions, blowouts, uncontrolled wells, and helicopter and marine accidents.

Table 1 presents a detailed analysis of oil and gas drilling and production accidents, including investigated causes and the number of fatalities and injuries. As shown in Table 1, most oil and gas disasters and accidents, particularly those occurring during the drilling process,

Table 1: Oil and gas disasters and accidents during the drilling process in Middle Eastern and Southeast Asian countries

Country	**Year**	**Cause of Accidents**	**Fatalities/ Injuries/Event**	**References**
United States of America	28 Oct 2014	Blowout explosion	400 evacuated	Kahraman *et al. (*2019)
Saudi Arabia	27 Dec 2013	Maintenance operation platform sank	3 fatalities	Zhang *et al. (*2020)
Malaysia	18 Aug 2014	Fell from height	3 fatalities	Mannan *et al. (*2016)
Iran	11 June 2015	Ship collided with platform	Damage to the platform	Rydell *et al.* (2019); de Sante *et al.* (2021)
Azerbaijan	5 Dec 2015	Fire explosion due to leakage	32 fatalities	Acır *et al.* (2017); Jaafar *et al.* (2018)
Mexico	26 Mar 2016	Drop objects	1 fatality	Halvorsen-Weare & Fagerholt (2017)
Norway	29 Apr 2016	Engine failure during helicopter operation	13 fatalities	Wanasinghe *et al. (*2021)
Canada	4 Aug 2017	Struck with head with pipe	1 fatality	Vachhani *et al.* (2016)
Pakistan	5 June 2017	Fire explosion	153 fatalities	Asad *et al.* (2020)
Malaysia	17 April 2018	Drill engine fire explosion	2 fatalities and 2 injuries	Alrbaihat (2023)

are prevalent in Middle Eastern and Southeast Asian countries. This trend is largely due to environmental diversity and the lack of robust industrial safety, health practices, and effective preventive measures in these drilling domains. Therefore, this review aims to address the impact of physical, chemical, and biological hazards on occupational accidents and illnesses in the oil and gas industries. The goal is to contribute knowledge that will help policymakers adopt effective OSH strategies to reduce occupational accidents and illnesses.

Occupational Accidents and Illnesses in the Oil and Gas Industry

The oil and gas industry is recognised as one of the most hazardous occupational environments. Workers in this sector are routinely exposed to various risks, including hydrogen sulphide, different mud components, gases, acids, coatings, drilling fluids, noise and vibration, various types of radiation, high heat conditions, and the handling of large objects. Depending on their degree and duration, such exposure can lead to occupational illnesses affecting the skin, lungs, and other organs.

Globalisation has had a marked influenced on workplace health and safety while impacting industrialised and developing nations. While industrialised countries (e.g., in Europe, the United States, and the Asia-Pacific region) report lower rates of workplace fatalities, these rates remain high in emerging nations. A significant factor influencing occupational health and safety regulation and practices is the shift in oil and gas production from central nations to peripheral countries, particularly in demanding and hazardous jobs (Donaghy *et al.*, 2023). Lower-paid workers in neighbouring countries often undertake complex and dangerous manufacturing tasks while more secure employment such as research, development, and marketing, predominantly occurs in core countries. This shift has led to a decrease in large company operations and an increase in small businesses and independent contractors, who must now pay greater attention to occupational health and safety issues.

In developing nations, challenges include the absence of national occupational health and safety policies, inadequate legislation, limited education, insufficient budget allocation for safety measures, and a lack of staff to support small businesses (OSHA, 2011). The industry segments (a) upstream (i.e., oil and gas exploration and production), midstream (i.e., transportation, marketing, and storage), and (b) downstream (i.e., refining, sales, and distribution) are illustrated in Figure 1.

Many oil and gas employees may be unaware that they are suffering from occupational illness. Diagnosing occupational illnesses can be particularly challenging. Especially if symptoms manifest after an employee has left their job, making it difficult to trace the cause directly to their workplace. Workers in this industry are typically exposed to a variety of health hazards, including chemical hazards (e.g., toxic, corrosive, carcinogenic, asphyxiating, irritant, and sensitising substances), physical hazards (e.g., noise, vibration, radiation, and extreme temperatures), and biological hazards (e.g., viruses, parasites, and bacteria) (Garg, 2019; Abas *et al.*, 2021). Table 2 in the document provides an overview of the potential health effects of critical processes in the oil and gas industry.

Figure 1: Segments of the oil and gas industry

Table 2: Oil potential health effects of critical processes in the oil and gas industry

Segments	Key Processes	Agents	Possible Health Effects	References
Upstream	Seismic survey and Evaluation Exploration and drilling Development and production Decommissioning	Pathogenicmic Organism's infection Transmitting vectors Radioactive sources Chemicals and additives Heavy metals Extreme temperatures Noise/vibration Mechanical Ergonomic	Cumulative trauma disorders Chronic obstructive pulmonary illnesses, gastrointestinal disorders Dermal and eye issues Neoplasms/cancer Heat stroke Stress Noise-induced hearing loss Drug and alcohol abuse	Tong *et al*. (2020); Wang *et al*. (2021); Garg (2022)
Midstream	Pipelines Transport and storage Marketing	Petroleum products (hydrocarbons) Dust from filing and scaling Cleaning of pipes and tanks	Dermal and eye issues Pulmonary disorders gastrointestinal disorders	Tullo (2016); Hafiidz *et al*. (2017); Abas *et al*. (2021)
Downstream	Product refining Petrochemicals Sales and distribution	Petroleum products (Hydrocarbons) Treatment chemicals Heavy metals Noise and vibration	Dermal and eye issues Gastrointestinal disorders Neoplasms/cancer noise-induced hearing loss	Sorensen *et al*. (2016); Jeelani *et al*. (2017); Rae *et al*. (2018)

The safety and health hazards faced by workers in the oil and gas industry can result in acute and chronic sicknesses. Acute effects occur immediately upon exposure to a hazard while chronic effects develop over an extended period. In the manufacturing sector, common risks include incorrect machine surveillance, repetitive motions, improper workstation arrangements, loud noises, vibration, slips, trips, falls, and exposure to various chemicals (Jeelani *et al.*, 2017). These factors contribute significantly to the occupational risks in this industry. Furthermore, the industry's extensive use of chemicals adds another layer of potential hazards. Figure 2 in the document presents data on the number of fatalities, fatal accidents, and Fatal Accident Rates (FAR) in the oil and gas industry from 2017 to 2021, as reported in the annual Safety Performance Indicators Report by the International Association of Oil and Gas Producers (IOGP).

Data from IOGP reveals notable trends in safety performance within the oil and gas industry. According to the Annual Safety Performance Indicators Report, there was an 8% reduction in the FAR and a decrease in fatalities from 33 in 2017 to 31 in 2018. The 33 fatalities in 2017 occurred across 30 separate incidents while the 31 fatalities in 2018 were the result of 27 incidents. This decline occurred despite a 2% increase in work hours reported by 46-member companies globally. In 2019, the industry saw a further reduction to 25 fatalities among IOGP member companies, down from 31 in 2018, which were the result of 22 separate incidents.

The work hours for 2018 and 2019 were similar, leading to a statistically significant 19% reduction in the FAR. Specifically, the FAR was 1.08 in 2017, decreased to 1.01 in 2018, and then to 0.82 in 2019, with 25 fatalities across 22 incidents. However, the 2021 safety report by IOGP indicated an increase in fatalities and injuries compared to those in 2020. With a 5% rise in reported work hours, fatalities increased from 14 in 2020 (12 incidents) to 20 in 2021 (15 incidents). The total recordable injury rate in 2021 was 0.77, a 10% increase from 2020's 0.70. Despite this, the lost time injury rate remained stable at 0.22. The FAR was 0.70 in 2020, with the 14 fatalities, and rose to 0.77 in 2021, following the 20 fatalities.

Chemical, Physical, and Biological Hazards in the Oil and Gas Industry

A workplace hazard refers to any risk encountered in a work environment. These hazards encompass a broad spectrum, including chemical and biological risks (biohazards) and psychological and physical risks. The role of the National Institute for Occupational Safety and Health (NIOSH) is crucial in addressing

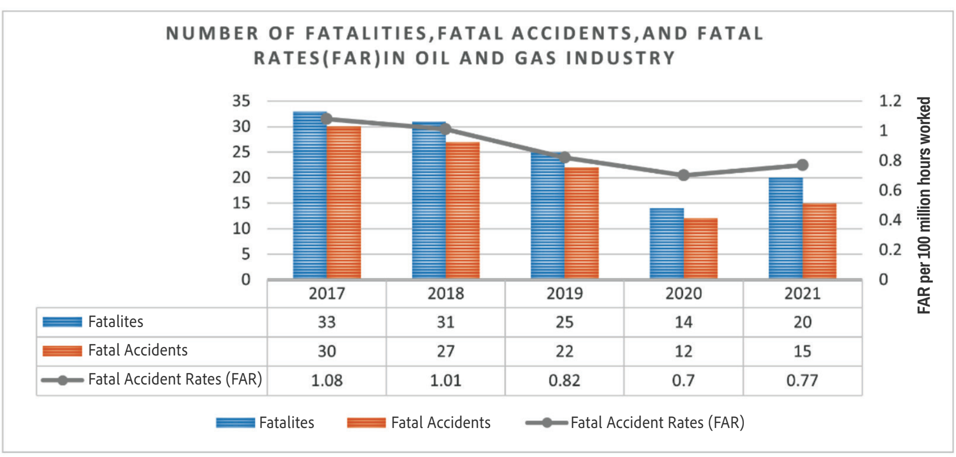

Figure 2: Number of fatalities, fatal accidents, and FAR in the oil and gas industry from 2017 to 2021

these concerns in the United States. NIOSH conducts investigations and research on various workplace health and safety issues and provides valuable recommendations based on their findings (Hafiidz *et al.*, 2017).

Chemical Hazards

In the petrochemical industry, chemical hazards refer to non-biological materials with the potential to endanger life or health (Sorensen *et al.*, 2016). These hazards, common in oil and gas worksites, pose occupational risks due to chemical exposure. Such exposure can result in acute or long-term adverse health effects (Vachhani *et al.*, 2016). Workers in this industry face various chemical hazards, including flammable materials, toxic, corrosive, oxidising, and compressed gases, and chemicals causing dermatological issues like contact dermatitis, eczema, and burns. Inhalation of dust, chemicals, metals, and compounds can lead to diseases like pneumoconiosis and asthma. Consuming contaminated food can also result in lead poisoning.

The widespread use of chemicals in both industrial and domestic settings highlights the need for awareness of their potential health impact (Vassie & Richardson, 2015). Exposure to hazardous chemicals can have immediate or long-lasting effects on health. These include neurotoxins, immune system stimulants, dermatologic irritants, systemic toxins, reproductive toxins, pneumoconiosis agents, and sensitisers. Effective risk mitigation such as using Personal Protective Equipment (PPE) can significantly reduce the risk of injury from hazardous materials (Zhang *et al.*, 2015; Zarei *et al*., 2019). Additionally, long-term exposure to various chemical hazards, including lead, cigarette smoke, silica dust, and engine exhaust has been linked to an increased risk of heart disease, stroke, and high blood pressure.

In the petrochemical industry, chemical hazards encompass a wide range of substances, including explosives, compressed gases such as propane, flammable and combustible liquids such as diesel and TNT, and organic peroxides used in polyester production such as methyl ethyl ketone peroxide.

Reactive oxidisers such as potassium permanganate are used as disinfectants and sterilisers (Podgórski, 2015; Zhao *et al.*, 2015). White phosphorus and carcinogens like benzene, along with other pyrophoric substances are common feedstocks in various petrochemical processes. Acids, including hydrochloric acid are utilised in food manufacturing and mineral processing. Hazardous chemicals in the industry also include reproductive poisons (e.g., lead and dioxins), sulfuric acid-based corrosives, sensitisers like latex, hepatotoxic substances (e.g., trichloroethylene), nephrotoxins (e.g., naproxen, an NSAID), and radioactive materials (uranium salts and plutonium). Some efforts, such as the ones made by Globally Harmonised System of Classification and Labelling of Chemicals (GHS), aim to enhance the safety of chemical management in the petrochemical industry (Tullo, 2016).

These chemicals pose numerous environmental, health, and safety hazards, with the most prevalent occupational hazards in the petrochemical industry being process hazards (such as leaks, spills, equipment malfunction, overpressures, corrosion, and metal fatigue). A tragic example occurred in 2016 when an explosion at a vinyl chloride plant in Coatzacoalcos, Mexico, operated by Aleichem and Pemex, killed 24 workers and injured 136 (Tullo, 2016). The incident led to the evacuation of some 2,000 nearby residents.

The incident in Coatzacoalcos highlights the severe consequence that can result from chemical hazards in the petrochemical industry. Another pervasive risk in this sector is hydrogen sulphide (H2S), commonly found in oil and natural gas reserves. H2S can irritate the lungs, throat, nose, eyes, and cause rapid, fatal poisoning at high levels (Feng *et al.*, 2014). National lists of occupational illnesses often include these chemicals, with most Sub-Saharan African (SSA) nations creating and maintaining lists regulating exposure levels to hazardous materials. These mandatory or suggestive regulations cover exposure through ingestion, inhalation, or skin contact and apply to other hazards like heat, noise, radiation, and cold (Asad *et al.*, 2017; Tang *et al.*, 2018).

Physical Hazards

Physical hazards represent a significant category of risks in the oil and gas industry, impacting employee health in various ways. These hazards include exposure to loud noise, inadequate lighting, poor ventilation, vibration, electricity, and radiation (Ekpenyong & Asuquo, 2017; Rae *et al.*, 2018; Dai & Tayur, 2020). The hazards can be defined as substances, aspects, or situations harmful upon contact. Physical hazards fall into either environmental or occupational categories. Key physical risks encompass ergonomics, radiation, heat stress, cold stress, vibration, and noise. Hand-held vibrating instruments such as grinders, needle guns, impact spanners, air drills, and chipping hammers are commonly used, particularly on offshore platforms. Regularly using these tools can lead to Hand-Arm Vibration Syndrome (HAVS), a significant health concern for workers.

Prolonged exposure to loud noise is another significant hazard, potentially leading to Noise-Induced Hearing Loss (NIHL), the most common industrial health epidemic. NIHL typically develops gradually, making early detection challenging. Beyond hearing loss, noise can also cause non-auditory effects like tinnitus, fatigue, nervousness, and discomfort, which diminish human performance. Each year, approximately twenty-two million workers in the United States are exposed to noise levels that could potentially harm their health.

Engineering controls are commonly used to mitigate physical risks. In many sectors, physical dangers are a frequent cause of injury. They may be inevitable in specific fields, like mining and construction, but humans have developed safety practices to reduce the likelihood of physical dangers at work over a period of time (Clement *et al.*, 2017). An employer would be obligated to supply face and eye protection, safety boots, overalls, and other protection needed to ensure his health and safety, which must be provided by the employer, according to the law. An employer must supply face and eye protection, safety boots, overalls, and other relevant PPE in a fabrication and welding workshop (Shaari *et al.*, 2020).

Extremes temperatures, significantly differing from standard room temperatures (68-74 degrees Fahrenheit), can cause heat and cold stress. Excessive heat can lead to a variety of heat-related illnesses such as heat exhaustion, heat syncope, heat cramps, and heat rashes. These conditions can impair cognitive functions, increasing the risk of workplace injuries (Yeh, 2020). While most healthy workers can acclimatise over time, some may struggle with extreme temperatures, necessitating heat tolerance assessments, especially after severe heat-related incidents (Yeh, 2020). In certain areas, hygiene legislation requires adequate ventilation in enclosed workspaces to manage temperature (Jenke *et al.*, 2021). Monitoring ambient heat levels and assessing the heat generated by employees' metabolism varies depending on the intensity of their work (e.g., light, moderate, or heavy) (Farina *et al.*, 2018). Additionally, acclimatisation should be emphasised, as it plays a vital role in enhancing an individual's ability to cope with heat stress.

Another primary cause of accidents in the petrochemical industry is chemical splashes, which can occur under various circumstances such as when a pipe or tank bursts under pressure or during the disassembly of pipes or valves. While it is challenging to detail every petrochemical process comprehensively and thus compile a complete list of all chemical risks present in this industry, it is essential to recognise that several well-known refining and petrochemical operations involve the use of a variety of chemical products (Fernández-Muñiz *et al.*, 2018). These operations pose significant risks, necessitating stringent safety measures and continuous monitoring to protect workers.

Biological Hazards

Biological hazards are another critical safety concern for workers in the oil and gas industry. While such hazards can impact all major industries, workers in the oil and gas sector are particularly vulnerable due to their exposure to a variety of bacteria, viruses, and parasites, which can significantly affect their well-being. The nature of work in rigging and extraction environments heightens this exposure, underscoring the importance of maintaining clean work conditions and stringent personal hygiene practices. Given that workers often operate close to one another, implementing social distancing and appropriate health protocols is crucial for mitigating the spread of illness and germs. If a worker falls ill on the job, it is vital for their safety and the safety of others that they are sent home to recover.

Over the past two decades, biological treatment technologies have emerged as significant complements to the petroleum industry's traditional physical and chemical methods. These technologies offer innovative strategies and approaches for oil production and refining and recommend safe, cost-effective remediation and disposal options. The scope of microbial process technology or biotechnology in this sector has extended beyond chemically or biologically enhanced oil recovery at commercial scales. Biotechnological processes also holds considerable potential in various areas, including oil production, fuel refining and upgrade, fine chemical synthesis, controlling souring during production, and air pollution reduction.

A biological hazard or biohazard is a danger from an organic source. In the oil and gas industry, biohazards encompass viruses, bacteria, mould, fungi, and natural toxins that can be present in the workplace. These hazards are often associated with poor hygiene, particularly in areas with water dispensers, ice makers, and galley spaces where room can be limited (Mrema *et al.*, 2015). Such environments require strict hygiene protocols and regular monitoring to ensure the safety and health of workers.

The oil and gas industries are pivotal in driving the global economy. However, drilling operations, a primary method for extracting petrochemicals from land and deep-sea environments, are closely linked with significant biological disasters, particularly sea pollution. Biological hazards or biohazards, pose complex challenges for Occupational Health and Safety (OHS) professionals due to the wide variety of potential agents and their impacts. These biohazards are not confined to the workplace; many can affect the surrounding community, particularly through the transmission of infectious diseases. Environmental biohazards, which outdoor workers may frequently encounter, underscores the importance of constant vigilance in the industry. It is essential to know the various oil and gas sector biohazards and implement measures to mitigate their impact (Zhang *et al.*, 2020).

To further elaborate, Table 3 summarises the health hazards contributing to occupational accidents and illnesses in the oil and gas industry. This table illustrates the events leading to these accidents and illnesses, providing a comprehensive overview of the health risks associated with these operations.

Elements Contributing to Occupational Accidents and Illnesses in the Oil and Gas Industry

The oil and gas sector exposes workers to numerous agents, leading to a wide range of occupational accidents and health hazards, including chemical, physical, and biological risks. This industry is inherently complex and diverse, resulting in elevated health hazards for its workforce (Milaković *et al.*, 2014; Ghazali & Halib, 2016). Further, the causes of occupational accidents and illnesses in this sector can be categorised into four main elements: Human factor, worksite conditions, management practices, and external influences. These contributing factors are depicted in Figure 3. This figure illustrates the interplay of these

Table 3: Summary of health hazards contributing to occupational accidents and illnesses in the oil and gas industry

First Order	**Second Order**	**Third Order**	**References**
Hazards Type	**Hazards Conditions**	**Accidents and Illnesses**	
Physical hazards	Exposure to loud noise	Hearing loss	Eyayo (2014); Fidancı & Ozturk (2015);
		Exhaustion and psychological stress	Guo *et al.* (2016); Garg (2022)
		High blood pressure	Hafiidz *et al.* (2017)
		Heart disease	Guo *et al.* (2016)
	Radiations	Cancer	Zahoor *et al.* (2015)
	Vibration	Headache and loss of balance	Garg (2022)
		Stomach problems	
		Physical exhaustion	Hafiidz *et al.* (2017)
	Hot and cold temperatures	Body cramps	Zhang *et al.* (2015)
		Heatstroke	
		Fainting	
	Electricity	Electrocution	Jeelani *et al.* (2017); Abas *et al.* (2021)
	Lighting	Visual system problems	Hafiidz *et al.* (2017)
Chemical hazards	Flammable materials	Fire and explosions	Vassie & Richardson (2017); Ariani *et al.* (2020)
		Inhalation of chemical elements	Tang *et al.* (2018)
	Corrosive	Chemical burns	IOGP (2016); Rae *et al.* (2018)
		Sensitivity of hands	Dai & Tayur (2020); Nkrumah *et al.* (2021)
	Oxidiser and compressed gases	Respiratory infections	Asad *et al.* (2017)
		Choking	
		Long-term detrimental health effects	Zhang *et al.* (2015)
	Toxic	Poisoning by toxic gases	Dai & Tayur (2020)
Biological hazards	Microbiological	Fungal illnesses	Yeh (2020); Jenke *et al.* (2021)
		Pollution	
	Water pollution	Cholera	
		Hepatitis	Agbola (2012)
	Air pollution	Tuberculosis illnesses	Mannan *et al.* (2016)
		Pneumoconiosis	Acır *et al.* (2017); Yang *et al.* (2021)
		Ischemic heart diseases	
		Lung cancer	
	Soil pollution	Bacterial illnesses	Milaković *et al.* (2014)

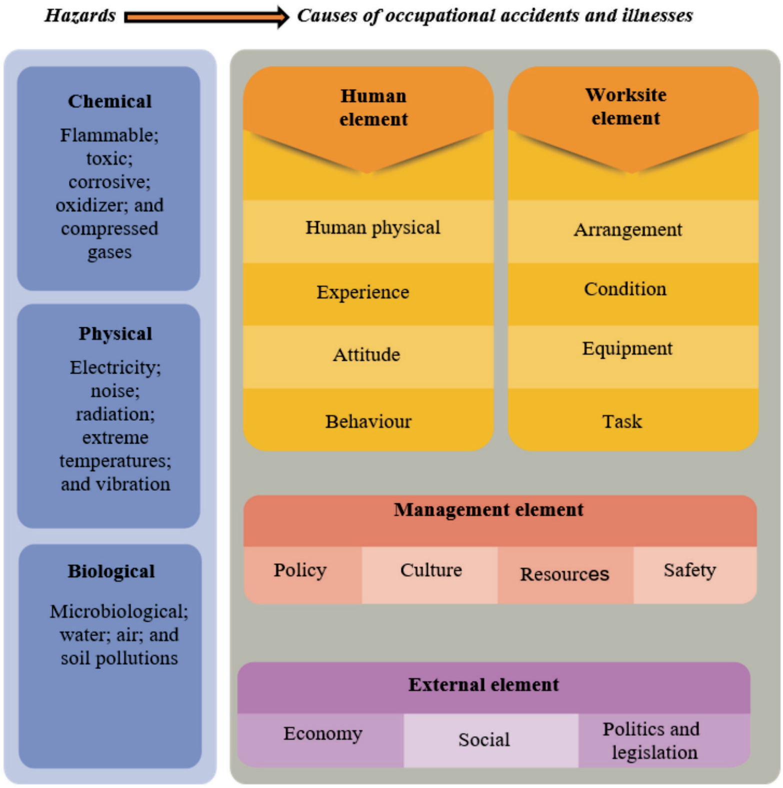

Figure 3: Framework for elements contributing to occupational accidents and illnesses in the oil and gas industry

elements, highlighting how they collectively impact the safety and health of employees in the oil and gas industry.

The human aspect undeniably affects occupational accidents and illnesses within the oil and gas industry. This aspect consists of four key factors: Physical influences (Li *et al.*, 2018), experience (Guo *et al.*, 2016), attitude (Nkrumah *et al.*, 2021), and behaviour (Jaafar *et al.*, 2018). Each of these factors contributes significantly to workers' safety and health outcomes. For instance, Abulhassn (2019) found that inadequate training and experience among workers significantly affected safety in offshore drilling operations. The study highlighted that inexperienced workers were more likely to be involved in near-miss incidents, emphasising the crucial role of experience in preventing accidents.

Similarly, a study by Naji *et al.* (2020) demonstrated the impact of workplace culture and attitude on safety. They observed that in environments where safety was not a core value, there was a higher incidence of accidents, emphasising the importance of fostering a positive safety culture. In addition to the human element, worksite conditions are crucial for ensuring safety and health. Proper worksite arrangement enables workers to perform their tasks safely and in ergonomically favourable conditions, reducing the risk of injuries and illnesses. For example, a study by Ismail *et al.* (2020) found that the layout and design of an offshore drilling platform significantly impacted the number of workplace incidents.

Their research showed that platforms with well-organised workspaces, clear signage, and accessible emergency exits had a lower rate of accidents and injuries. This finding is further highlighted by the tragic incident involving the Usumacinta rig in October 2007. While drilling at PEMEX's Kab-101 platform in the Bay of Campeche, adverse weather conditions led to the rig's cantilever deck striking the top of the platform's valve tree, causing a catastrophic oil and gas leak. The subsequent evacuation faced considerable challenges due to rough seas, resulting in 21 fatalities and one missing worker. Criticisms arose over the rig's structural integrity and emergency preparedness, highlighting the importance of robust design and effective safety measures in extreme working environments like offshore platforms.

Furthermore, the nature of the tasks undertaken at these worksites warrants close attention. Workers in the oil and gas industry are often involved in various activities, exposing them to various safety and health hazards (Rae *et al*., 2018). These hazards can be directly related to their job roles or indirectly induced by co-workers' actions. For instance, during a routine maintenance operation on an offshore oil rig, a worker responsible for operating heavy machinery may be directly exposed to risks such as malfunctions or accidents (Ismail *et al.*, 2020).

Meanwhile, another worker tasked with pipeline inspection could inadvertently induce additional hazards for their co-workers. If proper communication protocols are not followed (Ho *et al*., 2020), the inspection activity might lead to unexpected pressure changes in the pipeline system, posing a risk to other workers on the rig who are not directly involved in the inspection but are operating in close proximity. Key tasks that pose risks include working with flammable liquids, handling biohazardous substances, monitoring and repairing damaged pipelines, and working with explosive materials. Understanding and addressing these human and worksite-related factors are essential for minimising accidents and illnesses in this industry (Jaafar *et al.*, 2018).

In the oil and gas industry, the management element is important in shaping the landscape of OSH. This element, comprising policy, resource management, management culture, and safety management is the backbone of an organisation's approach to mitigate occupational accidents and illnesses. However, a safety policy manual, while fundamental, is insufficient. Its efficacy is notably limited if it stands alone, unaccompanied by a holistic and integrated safety management system. A critical examination of effective safety management, as illustrated in the study by Ajmal *et al.* (2022), reveals that the real strength of safety management lies in its comprehensive nature. Safety management should not be perceived merely as a set of directives in a manual but as a dynamic and integral part of the organisation's culture. This involves formulating policy and objective statements and ensuring they are adaptable and responsive to the evolving nature of workplace risks. Training programs, for example, should not be static, one-off events but ongoing processes that adapt to technological advancements and changing work environments.

Regular reviews and risk evaluations are significant; however, their effectiveness relies on how sincerely they are conducted and how rigorously their findings are implemented. The actual test of these evaluations is their ability to predict and prevent incidents before they occur rather than merely responding to them post-facto. For example, a study conducted by Carter *et al.* (2020) on offshore drilling operations in the Gulf of Mexico found that a proactive approach to risk evaluation, regularly updating their risk assessments with real-time data and employee feedback, could lead to significantly fewer incidents. This study highlights that the effectiveness of risk evaluations is not just in their execution but in how their insights are actively used to anticipate and mitigate potential hazards.

In addition, the role of employees in this system cannot be overstated. Their active participation in safety matters, from the low level of the organisation to the executive level is essential (Jaafar *et al.*, 2018). It requires generating an environment where safety concerns are openly communicated and addressed without fear of reprisal, in which organisations look to create a culture where safety is not just the responsibility of a designated few but a collective commitment. However, challenges persist in resource allocation (Pidgeon & O'Leary, 2017). Often, safety measures are seen as cost centres rather than investments in human capital and operational efficiency (Thiede & Thiede, 2015). This short-sighted approach can lead to underfunding critical safety initiatives, leaving gaps in risk management strategies. Lastly, the management culture plays a decisive role. A culture that prioritises safety and views it as integral to business success is likelier to foster a safer workplace. Conversely, a culture that views safety measures as bureaucratic hurdles will likely face higher risks of accidents and illnesses (Jaafar *et al.*, 2018).

While often undetected in accident investigations, external factors play an essential role in shaping the landscape of occupational safety in the oil and gas industry. Political and legislative environments, economic conditions, and social aspects form the essence of these external influences (Waring, 2019). While they may not be direct causative agents of accidents or illnesses, their indirect impact is significant. For instance, political decisions and legislative frameworks can dictate the rigour of safety standards and the stringency of their enforcement (Nandako, 2020). The risk of occupational hazards escalates in regions where such regulations are lax or poorly enforced.

Similarly, economic conditions can influence the allocation of resources for safety measures (Mohammadfam *et al*., 2017). Safety protocols might be underfunded in a strained economic climate, leading to compromised workplace safety. Similarly, the social aspect, often overlooked, is equally critical. Public awareness and societal attitudes towards workplace safety can pressure industries to adopt stricter safety measures. Conversely, a lack of public concern can lead to complacency in safety practices.

These external factors intersect with the human element in the workplace. Human behaviour, experience, attitude, and skills are at the forefront of occupational safety. Lack of experience or inadequate training can leave workers ill-prepared to handle hazardous situations (Jaafar *et al.*, 2018). Poor attitude and unsafe behaviour, possibly stemming from a lack of awareness or undervaluing of safety protocols, increase vulnerability to hazards. These human factors are pivotal in determining the degree of exposure to various hazards, be it chemical (Ariani *et al*., 2020), physical (Hafiidz *et al*., 2017), or biological (Yeh, 2020). Worksite conditions and task assignments also significantly influence safety. If not managed effectively, challenging tasks and poor worksite conditions can lead to workers neglecting safety protocols (Zhang *et al*., 2015).

This neglect not only exposes them to direct job-related hazards but also creates a domino effect, indirectly affecting the safety of their co-workers. Finally, the role of legislation and regulatory bodies cannot be understated. The effectiveness of OSH standards in reducing injuries and fatalities hinges on their existence and robust implementation and enforcement. To provide a comprehensive overview of how these elements interact and lead to occupational accidents and illnesses, Table 4 presents the sequence of events and relationships among these causes and their resulting health hazards in the oil and gas industry.

Conclusions

OSH hazards in the oil and gas industry are broadly categorised into physical, biological, and chemical hazards. If not managed effectively, these hazards can lead to serious occupational accidents, illnesses, and even fatalities. This review highlights the critical need for a comprehensive risk assessment approach tailored to each phase of oil and gas operations such as upstream, midstream, and downstream - due to the distinct hazards and varying levels of risk they present. By

Table 4: Summary of causes that lead to occupational accidents and illnesses in the oil and gas industry

First Order	Second Order	Third Order	Fourth Order	References
Human element (Immediate causes)	Human physical	Unsuitable size and body shape	Height size	Eyayo (2014); Li *et al.* (2018)
		Lack of strength		Golovina *et al.* (2016); Garg (2022)
		Lack of stamina and fatigue		Ariani *et al.* (2020)
		Poor health condition		Hafiidz *et al.* (2017); Abas *et al.* (2021)
		Intoxication and drug effect		Sorensen *et al.* (2016); Zarei *et al.* (2019)
		Stress		Garg (2022)
	Experience	Knowledge	Lack of knowledge	Guo *et al.* (2016)
			Confusion	Zhang *et al.* (2015)
		Lack of skill	Skills inappropriate to the tasks	Ariani *et al.* (2020); Nwankwo (2020)
			Lack of experience	Sorensen *et al.* (2016)
		Occupational accidents and illnesses record	Near misses	Tullo (2016)
			Involvements	Rae *et al.* (2018); Tang *et al.* (2018)
		Extensive experiences		Feng *et al.* (2014); Asad *et al.* (2017)
		Awareness of language and communication		Rae *et al.* (2018); Dai & Tayur (2020)
		Problems - illiteracy		Clement *et al.* (2017)
	Attitude	Towards organisation	Neglecting the reputation	Nkrumah *et al.* (2021)
Worksite element (Immediate causes)			Performance of an organisation	Yeh (2020)
			Neglecting organisation safety and health policy	
			Neglecting the organisation's safety procedures	
		Personal attitude	Satisfy with the level of safety	IOGP (2016)
			Performance excessive	Dai & Tayur (2020)
			Risks of accidents and illnesses	Nkrumah *et al.* (2021)
			Lack of confidence	Jenke *et al.* (2021)

Worksite element (Immediate causes)		Motivation/needs	Prioritising basic and psychological needs	Farina *et al.* (2018); Fernández-Muñiz *et al.* (2018)
	Behaviour	Error	Lack of focus	Mannan *et al.* (2016); Rydell *et al.* (2019)
			Violations	Wei *et al.* (2015); Jaafar *et al.* (2018)
	Worksite condition	Noise	Noise-induced hearing illnesses	Ezejiofor *et al.* (2013); Zhang *et al.* (2015)
			Insufficient lighting	
		Insufficient ventilation	In closed areas	
			Excessive heat rain	Jaafar *et al.* (2018); Rae *et al.* (2018)
		Poor facilities		Wang *et al.* (2020)
	Poor site management	Poor level of cleanliness and tidiness		Milaković *et al.* (2014)
		Poor waste management	No designated space or schedule	
		Working path and surface	Working path blocked	Milaković *et al.* (2014); Vachhani *et al.* (2016)
	Equipment and materials	Oil and gas materials	Unsuitable and in poor condition	
	Demanding tasks			Farina *et al.* (2018)
Management element (underlying causes)	Resource management	Capital resources	Prioritising profitability over safety	Mannan *et al.* (2016); Wang *et al.* (2020)
			Prioritising prices over safety	
		Human resources	Neglect safety and health elements during' recruitment selection	IOGP (2016); de Sant *et al.* (2021)
			Lack/no training provided	Nkrumah *et al.* (2021)
	Policy	Not in written form		Fernández-Muñiz *et al.* (2018)
		Lack of communication		Mrema *et al.* (2015)
		Complicated format/length		Kahraman *et al.* (2019)

Management Element (underlying Causes)	Safety management	Language safety procedure	Not in written form	Mannan *et al.* (2016); Rydell *et al.* (2019)
			Difficult to obtain and communicate to personnel	de Sant *et al.* (2021)
		Planning	Demanding working schedules	Wei *et al.* (2015)
			Working time to complete tasks	Jaafar *et al.* (2018)
			No safety meeting	Wang *et al.* (2020)
			No job analysis	Acır *et al.* (2017)
		Record and information management	Occupational accidents and illnesses are not recorded	Yang *et al.* (2021)
			Occupational accidents and illnesses are not reported	Milaković *et al.* (2014)
		Safety supervision	No/insufficient safety	Ghazali & Halib (2011)
			No/insufficient safety supervision by sub-contractors	
			Poor supervision by safety personnel	
		Management culture	Prioritising quality over safety	Asad *et al.* (2017)
			Occupational safety and health are not included as a successful project criteria	Yeh (2020)
			Poor affiliation between management and employees	Mrema *et al.* (2015); Zhang *et al.* (2020)
			Poor communication between management and employees	Rydell *et al.* (2019)
External element (Underlying Cause)	Politics and legislation	Insufficient legislation	Mandatory training and skills established	Tang *et al.* (2018)
			Insufficient regarding licensing	Clement *et al.* (2017); Shaari *et al.* (2020)
		Economy	Difficulty in the supply of services and materials	Jenke *et al.* (2021)
		Social	Clients neglected occupational safety and health issues	Milaković *et al.* (2014)
			Society neglected occupational safety and health issues	Gomaa *et al.* (2015)

understanding the underlying causes, including management practices and social factors, OSH professionals can more effectively address the immediate risks posed by human and worksite factors. This study shows the importance of a holistic risk assessment approach that addresses the immediate hazards associated with specific tasks and considers broader management and social influences. The review offers a framework for understanding how these diverse elements contribute to occupational risks, providing valuable insights for OSH professionals, policymakers, and industry stakeholders.

These findings are particularly significant for developing targeted interventions to reduce occupational fatalities and improve overall safety in the oil and gas industry. Future research could explore the development of more sophisticated risk assessment tools that integrate real-time data and predictive analytics to identify potential hazards before they result in accidents or illnesses. Additionally, studies could investigate the effectiveness of specific management practices and safety culture initiatives across different sectors of the oil and gas industry, providing further guidance on best practices for OSH management.

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Conflict of Interest Statement

The authors declare that they have no conflict of interest.

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