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A SYSTEMATIC INVESTIGATION OF ACCIDENTS IN PETROLEUM GEOPHYSICAL EXPLORATION (PGE)

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Abstract
The oil and gas industries remain an essential drive for the world economy. Petroleum geophysical exploration (PGE) significantly impacts the oil industry but is still trapped by fieldwork accidents. This study conducts an analysis of PGE fieldwork accidents, and some potential relationships between the causation and consequence have been suggested. These analysis results illustrate that the accident type that is most likely to occur varies with the conditions of the PGE fieldwork site, which requires a flexible forecasting strategy that suits the actual situation of each fieldwork. From the result, it is suggested that not all the factors impact the specific type of accident. Taking precautions against all types of accidents with the same strategy may not perform well. Allocating too many resources to manage the irrelevant factors is a futility for PGE companies in controlling the fieldwork risk.

Keywords: petroleum geophysical exploration (PGE), oil and gas, accidents, fieldwork.

Introduction

The oil and gas industries remain an essential drive for the world economy (Mojarad et al., 2018). For the last century, crude oil exploitation and exploration have occurred in the Niger Delta of Nigeria (Nwaichi & Osuoha, 2022). A significant amount of Nigeria's oil and gas reserves are in the swamp and offshore environments, with over 40,000 registered workers (Nwankwo et al., 2022). Following the signing of the Petroleum Industry Bill into law, the Nigerian Upstream Petroleum Regulatory Commission (NUPRC), as the successor agency of the Department of Petroleum Resources (DPR), is the upstream industry regulator mandated to drive several safety programs to protect people, environment, and assets through enforcement of laws and regulations. Oil and gas exploration encompasses the processes and methods of locating potential sites for oil and gas drilling and extraction (Cwinya-ai, 2016). The first people to look for oil and gas depended on surface signals like natural oil seeps, but advances in science and technology have made oil and gas exploration more effective. Managing the uncertainty inherent in exploration requires making choices based on various probabilistic and economic considerations. Indeed, exploration is risky, and managing exploration assets and associated operations is significant for oil companies. The risk cannot be eliminated but can be controlled and reduced by adopting appropriate workflow, conceptual, and technological innovations. Geological surveys are conducted using various means, from testing subsoil for onshore exploration to seismic imaging for offshore exploration.

Geophysical prospecting technology is indispensable for oil and gas exploration (Yang et al., 2021). This technique employs physical methods such as seismic, gravitational, and electromagnetic at the earth's surface to gather information regarding the physical properties of the subsurface mineral deposits. Because of this, it has become the basis for many mining businesses, including the petroleum industry. Petroleum geophysical exploration is based on seismic data and has been widely affected by deep learning technology in recent years (Jiang et al., 2022). However, a significant number of challenges are still preventing the advancement of petroleum geophysical exploration (PGE) (Chu et al., 2020). Indeed, the exploration and production of hydrocarbons is a high-risk venture (Suslick & Schiozer, 2004). The most significant obstacle has always been the numerous dangers inherent in fieldwork (Hasle et al., 2009). This is intrinsically linked to the nature of the job, as the exploration process in the wild entails numerous hazards, including but not limited to a wide variety of vehicles, drilling machinery, explosives, electricity, and fire (H.U. et al., 2013). The challenges include environmental, faulty equipment, wrong detailing, cake or expired explosives, poor or compromised supervision, and security.

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These challenges are peculiar to Nigeria due to inadequate policies that guide exploration activities. For instance, several offshore petroleum accidents in Nigeria have been attributed to lapses in the Petroleum Act (Ole & Herbert, 2022). In Nigeria's petroleum ecology, exploration entails tapping into unseen pressurized underground resources to extract petroleum resources to the surface. Extracted products are transported to refineries over long distances, often via pressurized pipelines or large ocean tankers. The refining and transformation of these products through complicated chemical processes are then carried out under high temperatures and pressure, making the process very hazardous. PGE entails managing complex processes at various stages in oil and gas exploration, which is highly subject to errors that could result in accidents or disasters. Nigeria is within the region where, most of the time, it is impossible to control natural events such as bad weather, low visibility at night, and being hurt by wild animals or plants. As such, the problem of petroleum exploration remains inevitable. Almost total dependency on imported technology and lack of readily available experienced workforce also contribute to these challenges, especially when it involves proper inspection of equipment and materials required for the acquisition and supervision processes. In addition, due to the rugged terrain of the Niger Delta region, a significant number of workers are required to do the necessary tasks at the worksite. This not only makes it more challenging to manage the employee's psychological factors, but it also makes the possibility of injuries higher. The PGE fieldwork is a high-risk occupation for a variety of factors.

Previous studies have reported significant incidents in the upstream sector, such as the Deepwater Horizon drilling rig explosion in April 2010, the Vermillion 380 oil rig explosion in September 2010, and the Chevron Nigeria limited oil rig explosion in January 2012 (Khan & Garaniya, 2013). Similarly, Ecuador's rainforest pollution, the Piper Alpha offshore disaster (1988), gas flaring in Nigeria, the Montara accident (2009), and the Macondo blowout (2010) are among the many PGE accidents (Arinaitwe, 2014). Accordingly, Ismail et al. (2014). examined several accidents in the offshore drilling of petroleum. Of 219 accidents recorded, the highest was blowouts at 46.1%, followed by storms and hurricanes with 15.1% and structural failures with 11.4%. High fatalities occurred at the Funiwa 5 platform in Nigeria with 230, the Piper Alpha platform in the North Sea with 167, and the Keilland semi-submersible in Norway. Ismail et al. (2014) noted that high fatalities were recorded at the Ocean Ranger fire and sinking, Java Sea sinking, Bohai 2 and Bohai 3 fire and sinking. The recent Seplat Majestic rig accident and the K.S. Endeavor explosion are among the PGE accidents in Nigeria's oil and gas sector. However, in some recent studies, scholars in other fields have successfully decomposed the collected accident reports and cases to extract critical information for supporting accident analysis in PGE (Bebeteidoh & Poku, 2016; Egbevurie et al., 2016; Igboanugo, 2010; Kadiri, 2011; Oghenefegor et al., 2021; Okezie et al., 2023; Omotehinse, 2022; Oyamienlen et al., 2023).

Because numerous factors could contribute to an increased risk at the PGE fieldwork site, it is essential to investigate the possible connections between these factors and the various accidents that could occur there. This will allow for the development of targeted threat forecasting that will assist in effectively avoiding accidents. Oilfield development aiming at crude oil production is a highly complex process that involves many uncertain risk factors affecting oil output (Zhong et al., 2016). Thus, threat forecasting and early warning about petroleum exploration development may ensure the operation and management of PGE fieldwork efficiently to meet the oil production plan of the country and sustainable development of oilfields. However, the literature contains very little research on the threat forecasting analysis of PGE fieldwork accidents, for which the critical problem is the lack of adequate and reliable data sources. The present study aims to establish a data-driven accident analysis in Nigeria's PGE.

Materials and methods

The present study adopted a cross-sectional survey research methodology. The PGE fieldwork needs to cover everywhere in the target land, so the workers are facing complicated situations, which requires the sample of accident cases for the study to be adequate to contain all the accident types. Many upstream companies in Nigeria have large employees. Their operation has extended to all areas in the Niger Delta region, and many exploration opportunities are ongoing. Since projects of this company have covered a wide range of time and space, the recorded accident cases in the process, therefore, covered all types of accidents that can happen in PGE fieldwork. This study's population sample comprises field engineers/operators and safety experts in the upstream petroleum industry in the Niger Delta region of Nigeria. This sample was extracted from international and national petroleum companies domiciled in the study area. The targeted population was approached between May and September 2023 and urged to participate in the study. Those who consented were briefed on the purpose of the study. A convenient sample of 282 participants was given the study questionnaire to fill out on the spot. In all, 216 questionnaires were correctly filled and returned.

Results and discussion

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Table 1 shows that of the 216 respondents who participated in the survey, 71% were men, and 29% were female. On the age distribution of the respondents, 26% are between 31 and 40 years, 25% are between 25 and 30 years, 22% are between 41 and 45 years, 16% are between 46 and 50 years, and 10% are above 50 years. On educational qualification, 18% of the respondents have a Higher National Diploma, 41% have a bachelor's degree, 28% have a master's degree, and 13% have a Doctorate Degree. 33% of the respondents have between 1 to 5 years of oil and gas experience, 31% of the respondents have between 6 to 10 years of oil and gas experience, 20% of the respondents have above 15 years of oil and gas experience, and 16% of the respondents have between 11- and 15-years oil and gas experience. The table also showed the distribution of the job categories of the participants. The highest proportion were drilling engineers (31%), followed by safety professionals (28%), process safety consultants (20%), geoscientists (11%), Academia (6%) and other categories (4%).

Table 1 Demographic representations

Variables	Category	Percentage (%)
Gender	Male	71%
	Female	29%
Age	25-30	22%
	31-40	26%
	41-50	38%
	50 above	10%
Education	HND	18%
	B.Sc.	41%
	M.Sc.	28%
	Ph.D.	13%
Job category	Drilling Engineers	31%
	Safety Professionals	28%
	Process Safety Consultants	20%
	Geoscientist	11%
	Academia	6%
	Others	4%
Experience	1-10 years	64%
	11 years above	36%

Table 2 shows the distribution of accidents in PGE fieldwork

Factor	%
Objects hitting injury	5.23%
Vehicle-related accidents	3.29%
Mechanical injury	7.32%
Electric shock	4.19%
Drowning	3.29%
Fire	7.03%
Falling injury	7.77%
Accidents involving explosives	34.54%
Acute occupational hazard	3.74%
Hurt by animals or plants	3.29%
Conflict with local people	10.0%

Table 2 shows the descriptive statistics on the respondents' perceptions of the likely percentage of accidents in the PGE industry. The result shows that the portion of the accident type "Accidents involving explosives" is the most

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significant (34.54%) among all accidents, indicating that accidents involving explosives are the most common in the PGE fieldwork. Apart from this, the type "Conflict with local people (10%)", "falling injury (7.77%)", "accidents involving explosives (7.32%)", and "mechanical injury (7.32%)" also take up a more significant percentage. The next is "fire (7.03%)", "objects hitting injury (5.23%)" and "electric shock (4.19%)", indicating a substantial impact that the equipment and energy sources have on the PGE fieldwork. Last, the "Acute occupational hazard (3.74%)", "drowning (3.29%)", "vehicle-related accident (3.29%)" and "Hurt by animals or plants (3.29%)" share nearly the same percentage, showing a relatively low probability of occurrence of these accident's types.

Discussion

The present study examined accidents in PGE. The statistics from Table 1 suggest that the study's participants who took part in the survey were seasoned professionals in the oil and gas industry. The survey also indicated the participants' level of education was high, and the demographic data also suggested that based on the respondent's level of education and years of experience, they have reasonable knowledge about the issues, challenges, and needs of the upstream industry relating to accident occurrences in PGE. Indeed, the participant's level of industry experience enhances the reliability of this study, as it indicates that most participants have vast experience in the oil and gas industry. Vehicle-related accidents, electric shock, fire, accidents involving explosions, and injuries caused by animals or plants are highly correlated with seasons. Time is an essential factor that affects vehicle-related accidents, mechanical injury, fire, and acute occupational hazards.

In all accident types, except objects hitting injury, mechanical injury, electric shock, and fire, the other types have a strong relationship with the terrain. Besides, three types of accidents, including objects hitting injury, accidents involving explosives, and acute occupational hazards, are highly correlated with the weather at the accident site. For time, night has a noticeable influence on accidents, which two types (mechanical injury and fire) are likelier to have the highest grey relational degree. Additionally, vehicle-related accidents are more likely to occur in the morning, and acute occupational hazards are more related to the afternoon. For terrain, vehicle-related accidents and acute occupational hazards may have the highest relevance to the plateau area. In contrast, explosions and drowning have the highest grey relational degree in the sea.

Moreover, falling and animal-related injuries could be more related to plain areas. For weather, it is very consistent with our common sense that accidents are more prone to occur in bad weather. Three types of accidents, drowning, explosion and acute occupational hazard, show the highest grey relational degree on rainy days.

Conclusions

This study conducts an analysis of PGE fieldwork accidents, and some potential relationships between the causation and consequence have been suggested. These analysis results illustrate that the accident type most likely to occur varied with the conditions of PGE fieldwork site, requiring a flexible forecasting strategy that suits the actual situation of each fieldwork. From the result, it is suggested that not all the factors impact the specific type of accident. Taking precautions against all types of accidents with the same strategy may not perform well. Allocating too many resources to manage the irrelevant factors is a futility for PGE companies in controlling the fieldwork risk. Therefore, with the findings, fieldworkers and safety managers can focus on specific accident types to achieve precise risk prevention, finally improving the PGE fieldwork safety management.

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