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Risk Matrix as a Tool for Risk Analysis for Work-Related Hazard in Offshore Installation in the Oil and Gas Industry

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This study aims to investigate the likelihood of hazard occurrence, the frequency level, the level of severity, and the consequences of work-related hazards in Offshore Installations. This study was a cross-sectional design assessment and the instrument used for this study was a well-structured questionnaire on Analysis of Work-related Accidents which was sent to e-mails of oil and gas workers. The reliability of the instrument was assessed using Cronbach's alpha. Data analyses were carried out using descriptive statistics, Risk Matrix, and Fault tree analysis. The 4 by 4 risk assessment matrix for the likelihood and consequences showed that 12 of the hazard were categorized as having high risk and Wind/Strong current was classified as extreme risk, However, 5 of the identified hazards, H5, H6, H7, H8 & H10 are risks that can be easily controlled to prevent an incident from occurring. All the offshore risks identified were either rated as high or extreme, which indicated that offshore hazards have severe consequences for the People, Environment, Asset and Reputation of the company. Therefore, high safety measures must be put in place to control these risks.

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1. INTRODUCTION

According to new research [1], “when we refer to hazards concerning occupational safety and health, the most commonly used definition is 'A Hazard is a potential source of harm or adverse health effect on a person or persons, and risk is the likelihood of an incident to occur”. “The terms Hazard and Risk are often used interchangeably. Several studies have revealed that the majority of occupational accidents are caused by people rather than unsafe working environments” [2,3]. “Findings indicate that approximately 80 percent of occupational injuries are caused by at-risk behaviors while 15 percent are caused by risky working conditions and the last 5 percent is inevitable” [4,5].

Marhavilas, & Koulouriotis [6], defined “Risk assessment as an essential tool for the safety policy of a company. It is the overall process of risk identification, risk analysis, and risk evaluation”. “These risk assessments are usually carried out based on a risk assessment matrix. Risks can be assessed at an organizational level or departmental level for projects, individual activities, or specific risks. We employ different tools and techniques that may be appropriate in different contexts” Valis & Koucky [7]. “Risk assessment is a systematic use of available data to determine how often specific events may occur and the magnitude of their likely consequences. The risk assessment is the central part of the risk management process, which purposes to establish a proactive safety strategy by investigating potential risks” [8,9].

“Offshore operations have always been very challenging due to technological and operational complexities in combination with harsh environmental conditions. Geological uncertainties, high-pressure flammable fluids in the presence of ignition sources, complicated structural layouts, limited response time allowance, and difficulty of control and communication are some of the critical factors that pose clear threats towards safe operations and may result in high-consequence events i.e., blowouts” [10]. “Furthermore, offshore oil and gas is a high-risk sector where workers face not only process hazards associated with the exploration, storage, and processing of hydrocarbons on platforms but other forms of hazards related to the harsh working environment and transportation” [11]. These high-risk operations present potential for accidents, injuries, and, in some cases, even death in the offshore environment. There are several common causes of offshore accidents and injuries such as transportation to rigs, object accidents, equipment failure and malfunction, fire hazards and blowouts, substance and chemical exposure, weather exposure, physical demands, and poor safety and training. “Every year, hundreds of people die and thousands of them are injured during performing their tasks in oil and gas drilling and production industries” [12]. “Due to the unpredictable and hazardous nature of the operation, several chemical, safety, environmental, and ergonomic hazards have been reported for decades all over the world” [13,14]. However, several fatalities and life-severe injuries have been indicated during onshore and offshore drilling and maintenance operations around the globe.

“Offshore oil and gas operations are associated with several safety, ergonomic and environmental hazards and therefore are considered the most challenging profession worldwide” [15]. “There are high injuries and accident rates among offshore oil and gas workers due to the lack of effective health and safety awareness of safe oil and gas drilling activities” [14]. “In the years 2007–2012, the occupational fatality rate of the oil and gas drilling industry was 2.5 times higher than the construction industry and 7 times higher than the general industry” [16]. “Furthermore, there are many underlying risk factors involved in a high rate of oil and gas drilling fatalities, critical accidents, and life-threatening injuries” [17,15]. “Whereas, due to the rapid change in the environment and advancement in drilling technology, rig workers have to face new challenges every day regarding health and safety” [14-16]. “Oil and gas drilling workforce have to deal with life-threatening conditions and injuries while performing their jobs” [18].

According to Adugbo [19], “data collated from the Department of Petroleum Resources (DPR) in Nigeria showed that fatalities of Nigerian oil and gas workers hit 217 from 2010 to 2015, of which 54 of the death cases were work-related fatal incidents”. “Though, it has been argued that primary data about occupational injuries or fatalities from operations in the Nigeria oil and gas sectors are most times hardly made public`, underestimated, or nonexistent” [20]; (Ezejiofor *et al*., 2014). In the Nigeria oil and gas context, there is a high volume of work that has been done on how the operational activities (exploitation and exploration) of the oil and gas companies impact the environment. However, there are limited studies and a scarcity of information on the risk assessment matrix that will differentiate relative risks to facilitate consistent and improved decision-making for offshore installation in the oil and gas industry [21].

This research would concentrate on the Niger Delta region of Nigeria's oil and gas industry. The Niger delta area is very rich in biodiversity and it's directly on the Gulf of Guinea at the Atlantic Ocean in Nigeria which makes it the zone with the highest crude oil and gas reserve in Nigeria. Covers about 70,000 km^2 and makes up 7.5% of the Landmass consisting of nine states Abia, Akwa Ibom, Bayelsa, Cross River, Delta, Edo, Ondo, and Rivers (Ugbomeh & Atubi, 2011).

2. METHODS

The research method that was used for this study was a cross-sectional design in which data were collected in the study area within the same period. This design is relevant as it involved collecting data from respondents and presenting them without manipulation. Consequently, a quantitative method was employed to assess and investigate the likelihood of hazard occurrence, the frequency level, the level of severity, and the consequences. This study adopted a stratified sampling technique. This technique involves dividing the entire population into smaller groups or strata (according to their department) to finish the sampling process. The researcher stratifies the population before proportionally selecting a sample at random. The instrument used for this study was a well-structured questionnaire sent to e-mails of oil and gas workers in Akwa Ibom state and the Rivers state of Nigeria for the collection of data to provide answers to the questions. A questionnaire containing six sections consisting of questions on demographics, hazards likely to occur in an offshore environment, injury types experienced by offshore workers, injured body parts prevalent among offshore workers, types of accidents in the offshore environment and consequences of accidents in the offshore environment were used in the data collection phase of the study.

2.1 Study Area

The study was performed using population personnel that work offshores in selected oil and gas industries in Akwa Ibom and Rivers state respectively as shown in Fig. 1. The population of this study covers Maintenance personnel, Marine Engineers, mooring masters, Operations personnel, Engineers, Asset owners, Emergency Responders, and Medics in selected oil and gas offshore facilities of the company operating in Rivers and Akwa Ibom state irrespective of the level of education, sex, job specialty, ethnicity, etc.

2.2 Instruments

The research instrument adopted was the questionnaire method. A variety of four-point Likert scales ranging from 1 (strongly disagree) to 4 (strongly agree) was used. The constructs for the work-related injuries and some demographic variables were obtained from well-Structured Health and Safety questionnaires [21]. The questionnaire was adopted to fit with the practices in the offshore installations.

Hazards Likely to Occur in Offshore Environment: This measures their perception of factors that can cause hazards in the offshore environment. 15 questions were asked to elucidate their response as adopted from the offshore safety questionnaire [21]. An example of such a question is; how likely is wind/strong current to occur in an offshore environment?

Injury Types Experienced by Offshore Workers: This measures their opinion on the common injuries experienced in an offshore environment. 10 investigative variables were used to find out their response as embraced from the offshore safety questionnaire [22]. A sample of the question was if laceration was probable to appear offshores. "Others" was used in the questionnaire to represent Musculoskeletal Disorders.

Injured Body Parts Prevalent among Offshore Workers: This measures their Opinion on the most affected Body Part when an Injury Occurs Offshores. 15 body parts were identified from the offshore safety questionnaire [22]. Questions were asked on if the hand is a prevalent body part to get injured.

Types of Accidents in Offshore Environment: Respondents were asked to carefully choose accidents prevalent in an offshore environment. 8 investigative variables were used to find out their response as embraced from the offshore safety questionnaire [22]. Industrial chemical accident was asked to know their perception of the likelihood of such accident to occur.

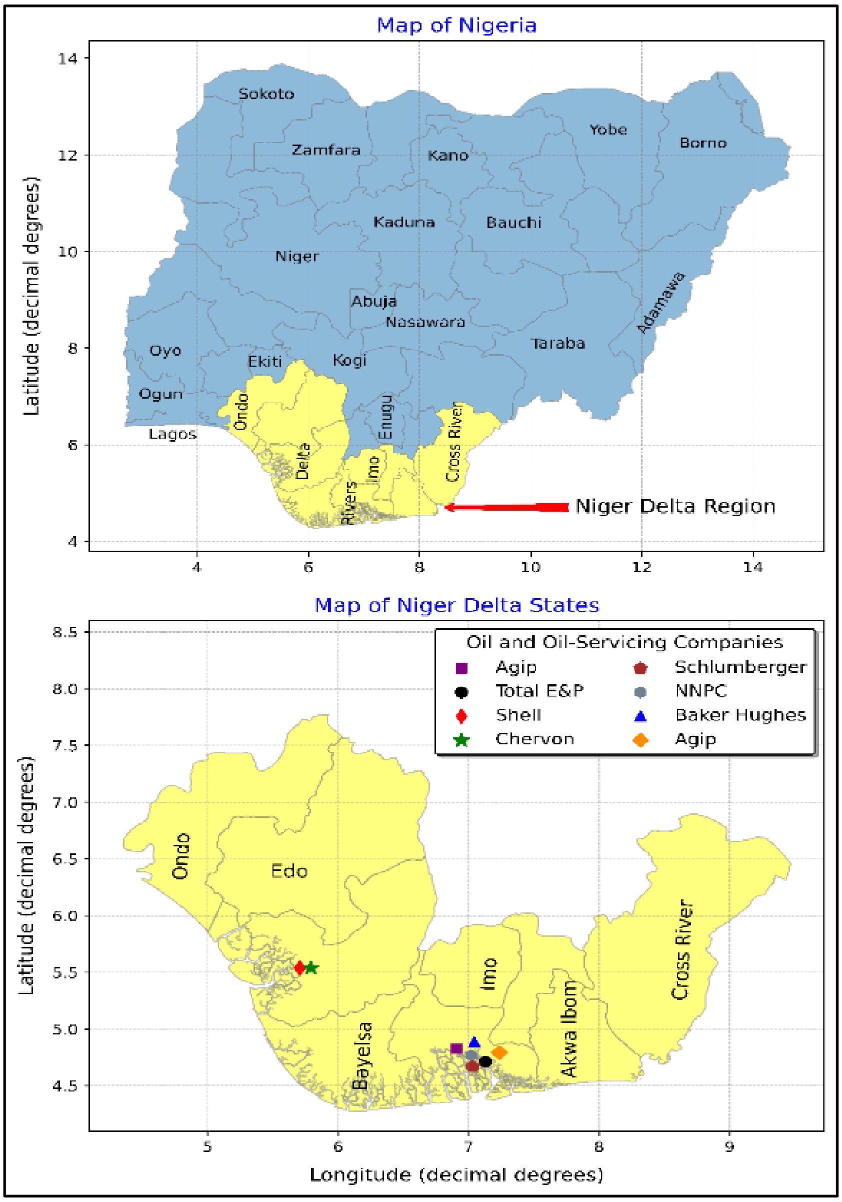

Fig. 1. Map of Nigeria showing Niger Delta Area, the oil & oil servicing companies in the region
Source: https://www.sec.gov/Archives/

Consequences of Accidents in Offshore Environment; Interviewees were asked about their perception on the effect of accidents offshores. 8 investigative variables were used to find out their response as embraced from the offshore safety questionnaire [22]. Effect on the personnel was one of the questions asked by the researcher to find out the response on the likelihood of the consequence to happen.

2.3 Data Analysis and Procedures

The responses from the participants were analyzed using SPSS version 26 and the coding was done according to the Likert scale used for the questionnaires. Composite scores were computed for each of the constructs and reliability was done using Cronbach alpha. A quantitative method was employed to assess and investigate the likelihood of hazard occurrence, the frequency level, the level of severity, and the consequences.

3. RESULTS

Table 1 shows the Questionnaire response rate; while Table 2 shows the Likelihood of Hazards occurring related to work-related accidents

Table 1. Survey response rate

Survey Parameters	Niger Delta Oil and Gas Companies workers	
	No. of Questionnaires	Percentage
Total copies of questionnaires distributed	450	100%
Unreturned copies of questionnaires	70	15.55%
Incomplete copies of questionnaires	55	12.00%
Completed and usable questionnaires	325	72.44%

450 questionnaires were shared and 325 questionnaires were properly filled and usable which accounted for 72.4% as shown in Table 1. The response from respondents shows the Likelihood of Hazards occurring related to work-related accidents. Work-related hazards with the likelihood of occurring are Wind/Strong current, Loss of buoyancy or sinking, and adverse weather and sea condition/heavy storms respectively are more likely to occur while Shallow waterways/poor visibility and Malfunction of machinery are less likely to occur as shown in Table 2. From accidents likely to occur offshores, equipment failure is the accident that would most likely lead to injuries (Table 3).

Fault tree analysis is a top-down approach to problem-solving wherein the starting point of analysis is the undesired event [7]. Fig. 2 shows a fault tree analysis of the equipment failure which is the accident that would lead mostly to injuries as shown in Table 3. Equipment Failure as shown in Fig. 2 is the undesired event and the hazards that can lead to the top events are remote/power/cooling/gauging system failure or malfunction of machinery. Root causes of Remote/power/cooling/gauging system failure hazards are the poor electrical connection that can cause the system to shut down or poor maintenance of mechanical parts. Malfunctioning of Machinery whose root cause could be misaligned tightness during maintenance or loss of connections e.g. unexpected outage due to power failure.

Table 4, shows the risk evaluation of hazards likely to occur in the offshore environment. From the table, H5, H6, H7, H8 & H10 are risks that can be easily controlled to prevent an incident from occurring. To prevent H5 from occurring, ensuing the 3 elements that causes fire are not present at all times. H6 and H10 can be prevented by ensuring periodic examinations are carried out on the pipelines, H8 which is very critical to ensure accident are prevented offshores is to ensure that personnel are not over worked by ensuring there is a work schedule with frequent breaks in-between the shift, H7- can be avoided by ensuring a Job Hazard Analysis (JHA) is carried out for non-routine job or high-risk job and persons not involved in the task are not found around the worksite. The values for the likelihood were adopted from the mean of Work-Related Hazard from Table 2, while the severity was gotten from the average of common injuries associated with the hazard. The risk value is gotten by multiplying the likelihood and severity to get the risk score. The highest risk score was 8.21 which was extreme while the least risk score was 5.20 which is high. Table 5 shows the Risk Assessment Matrix of the likelihood and severity of work-related hazards in offshore installations.

4. DISCUSSION

The observations from the study showed 12 hazards as high-risk; Adverse weather and sea conditions/heavy storms**,** Shallow waterway/poor visibility, Kidnapping/Piracy and Bandit attack, Fire/Explosion, Blowout/release of fluid or gas, Heavy object dropping or falling load/collision, Breakage/Fatigue, Capsizing/ overturning/ toppling, Corrosion/debris accumulation, Remote /power/cooling/gauging system failure, Loss of buoyancy or sinking, Malfunction of machinery. These hazards are rated high because the consequences if they occur during operations could lead to a major negative effect on People, Environment, Assets, and Reputation (PEAR). Strong current/wind had an extreme value which implies that if the hazard occurs, the outcome would be catastrophic.

Furthermore, the risk matrix showed that adverse strong current/wind, Loss of buoyancy or sinking, or weather/heavy storm will very likely result in major injuries when it occurs. This result is in tandem with [23], whose study showed that such extreme operating conditions can disrupt the offshore infrastructure and cause major accidents, posing a great challenge to operators. Other main vessels/heavy object dropping or falling load/collision, Fire/explosion, Blowout/ release of fluid or gas, and Capsizing/ over-turning/toppling will likely result in a fatality as they occur.

Table 2. Likelihood of Hazards occurring related to work-related accidents

Work-Related Hazard	Frequency Distribution							Likelihood of occurrence (%)
	Mean	Mode	Std. Dev.	Very Unlikely	Unlikely	Likely	Very Likely	
Adverse weather and sea condition/heavy storms	2.79	3	0.913	37	66	151	71	68.3
Shallow waterway/poor visibility	1.92	2	0.898	123	125	56	21	23.7
Kidnapping/Piracy and Bandit attack	2.47	2	0.995	63	104	101	57	48.6
Wind/Strong current	2.95	3	0.804	16	65	163	81	75.1
Fire/Explosion	2.50	3	1.017	68	87	111	59	52.3
Blowout/release of fluid or gas	2.14	2	0.971	98	118	74	35	33.5
Heavy object dropping or falling load/collision	2.53	3	0.992	62	86	120	57	54.5
Breakage/Fatigue	2.14	2	0.978	101	114	75	35	33.8
Capsizing/overturning/toppling	2.34	2	1.004	79	105	93	48	43.4
Corrosion/debris accumulation	2.14	2	0.988	103	111	75	36	34.2
Remote/power/cooling/gauging system failure	2.21	2	0.990	92	113	80	40	36.9
Loss of buoyancy or sinking	2.85	3	0.864	26	71	154	74	70.2
Malfunction of machinery	1.88	2	0.923	140	104	61	20	24.9

Table 3. Accidents resulting in Injuries

Accidents	Mean	Std. Deviation	Analysis N
Barges and tug boat accidents	1.91	.876	325
Drilling rig accidents	2.93	.852	325
Equipment failures	2.98	.809	325
Deck accidents	2.25	.999	325
Inland accidents	2.53	.957	325
Industrial chemical accident	1.76	.767	325
Shallow drilling “Jack-Up” rig accident	2.93	.821	325
Offshore installation platform accidents	2.98	.791	325

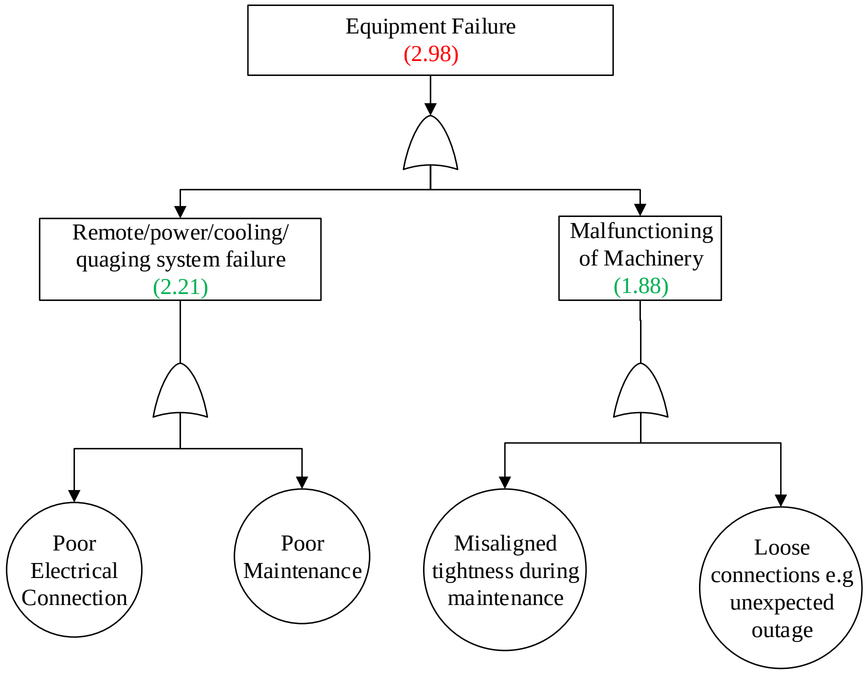

Fig. 2. Equipment failure

Table 4. Risk matrix

ID	Hazards	Likelihood	Severity	Risk	Risk Evaluation
H1	Adverse weather and sea condition/heavy storms	2.79	2.80	7.80	High
H2	Shallow waterway/poor visibility	1.92	2.70	5.20	High
H3	Kidnapping/Piracy and Bandit attack	2.47	2.68	6.61	High
H4	Wind/Strong current	2.95	2.78	8.21	Extreme
H5	Fire/Explosion	2.50	2.82	7.03	High
H6	Blowout/release of fluid or gas	2.14	2.74	5.87	High
H7	Heavy object dropping or falling load/collision	2.53	2.68	6.78	High
H8	Breakage/Fatigue	2.14	2.62	5.60	High
H9	Capsizing/overturning/toppling	2.34	2.80	6.55	High
H10	Corrosion/debris accumulation	2.14	2.82	6.02	High
H11	Remote/power/cooling/gauging system failure	2.21	2.76	6.10	High
H12	Loss of buoyancy or sinking	2.85	2.79	7.96	High
H13	Malfunction of machinery	1.88	2.80	5.26	High

Table 5. Risk assessment matrix shows the risk assessment matrix of the likelihood and severity of work-related hazard in offshore installations

		Severity			
		Negligible (1)	**Moderate (2)**	**Major (3)**	**Catastrophic (4)**
Likelihood	Almost Certain (4)		H1, H2, H3, H5, H6		H4
	Possible (3)			H7, H8, H9, H10	
	Unlikely (2)				H11, H12, H13
	Very Unlikely (1)				
		Risk Evaluation			
		Low	Moderate	High	Extreme

The most frequent cause of accidents in offshore installations is Blowout [24].in words of [25], Blowouts can lead to the loss of life, environmental damage, and loss of resources, etc. Capsizing/overturning refers to a situation where the vessel at sea list to one side to such an extent that is not able to regain its original position, leading to tipping over of the vessel in the water and making it unsafe for both crew and machinery onboard. The capsizing of the vessel can lead to loss of life and vessel damage.

5. CONCLUSION

In Summary, the findings from this work showed that 12 hazards were classified as High risk. Their Hazard IDs are H1, H2, H3, H5, H6, H7, H8, H9, H10, H11, H12, and H13. They are evaluated as high risk because if such an incident occurs, the consequence would range from moderate to catastrophic effects on the people, environment, assert, and reputation of the company involved. Wind/Strong current was classified as extreme, which shows that if such an incident occurs in an offshore installation, the effect would be catastrophic. All the offshore risks identified were either rated as high or extreme, which indicated that offshore hazards have severe consequences to the personnel and the facility. Therefore, high safety measures must be put in place to control these risks.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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