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HAZARD IDENTIFICATION AND EVALUATION IN FLOATING PRODUCTION, STORAGE AND OFFLOADING (FPSO) TO ENABLE PROPER MANAGEMENT OF RISK IN THE OFFSHORE ENVIRONMENT

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ABSTRACT

The study evaluated hazards and risk associated with the FPSO operation in Nigeria offshore environment with the aim of enabling proper management of risk peculiar to the environment. The study adopted a survey research design and structured questionnaires were used to obtain data from the study population, which comprised of three selected FPSOs (YF FPSO Front Puffin OML 113, FPSO Mystras NPDC OML 119 and FPSO Sendje Berge Okwori field OML 126). The study population was 377 and the sample size derived was 278, then 236 respondents provided the valid data used for the analysis. The findings revealed that 12 critical hazards occurring and each of them lead to different magnitude of impact on operations. In order to proffer possible solution to the identified hazards, the study recommend that Health, Safety and Environment (HSE) practice needs to be independently regulated in manner that regulatory agencies will be separated from revenue generation unit(s). Also, risk management processes and compliance should not be left alone in the hands of operating companies in Nigeria to pursue and implement, without government full participation in ensuring adherence to strict HSE code. Finally, there is need for accurate and timely incident and accident reporting and also establishing separate body for data collection for researchers.

Keyword: Floating Production, Storage and Offloading, Hazard, Risk Assessment

I. INTRODUCTION

The offshore production concept has been around for some decades. The structures used in an offshore production are different, depending on size and water depth. In the last few years, there has been a pure sea bottom installation with multiphase piping to shore, and no offshore topside structure at all. One of the very notable forms of offshore production is the Floating Production, Storage and Offloading (FPSO). Initially floating production systems were introduced for early production or marginal field development. Currently, their potential for deep water development is of interest. There are now over 70 FPSOs working all over the world or under construction and in use (FPSO.com, 2017). Most of the applications are conversions of ocean-going oil tankers in relatively benign environmental areas such as Southeast Asia, West Africa and offshore Brazil near the Equator. Some vessels operate in the North Sea, for which the design events are winter storms. A few FPSOs are used in the tropical cyclone prone areas of the South China Sea and offshore Northwestern Australia, and several are under consideration for the Gulf of Mexico (ABS, 2002).

A critical area of focus in this study is the oil and gas processing activity. The environment is exposed to improper waste disposal techniques, spills, produced water discharges, or other byproducts that can have harmful impacts on the environment in the event of an uncontrolled release. The containment and disposal of the wastes is a main priority (Arthur, *et al*, 2009). Therefore occupational health practice in the oil and gas industry must take more concern to the known hazards that exist in the particular location of operation in order to prevent and control their occurrence (Aliyu & Saidu, 2011). Occupational risks and hazards are the health problems that employees face in their work environment and how those health problems affect the health status of employee and their families (Aliyu & Auwal, 2015).

II. STATEMENT OF THE PROBLEM

In economic terms, ILO (2009, 2006, 2005) estimates that roughly 4% of the annual global Gross Domestic Product (GDP), or US$1.25 trillion, is siphoned off by direct and indirect costs associated with occupational accidents and diseases such as lost working time, workers' compensation, the interruption of production and medical expenses. Similarly, Schouwenaars (2008), in analysis of refinery losses due to 123 refinery fires over a 15 year period from 1965 to 2000, demonstrated a trend of rising losses over the period. He added that between 1998 and 2000 alone, the total loss from refinery and petrochemical incidents around the world exceeded $900 million. In fact, Adei and Kunfaa (2007: 164) have reported that the cost of accident as a percentage of the GDP for developing countries like Ghana is estimated to be around 7%. The UK's Health and Safety Executive (2012) also estimates that, on an annual basis, accident costs the oil platform 14.2% of its potential output.

Consequently, in Nigeria, according to the energy mix report (2013), there have been records of several preventable accidents in offshore operations in recent years. A typical example, is the hazard incident which took place had fire broke out on-board the Chevron's Funiwa North Apoi shallow-water jack up drilling rig in 2012, which was classified as the worst gas blow-out in Nigeria. About 154 personnel were on the rig and a support barge and two lives were lost while several others sustained injuries. Also, Funiwa five well operated by TOPCON experienced a blowout, which resulted to an estimated 146,000 barrels of oil spilled into the ocean during the two weeks blow out.

Recurring incidences of this kind demands that an in depth study be carried out aimed at evaluating hazards in floating production, storage and offloading operation to enable proper risk management in the offshore environment.

III. OBJECTIVE OF THE STUDY

1. To identify and evaluate hazards and risk in Floating Production, Storage and Offloading (FPSO) to enable proper management in the offshore environment.
2. To proffer possible solution on best practices aimed at addressing the ills associated with the current status of occupational hazards in the operation of FPSO.

IV. STUDY AREA

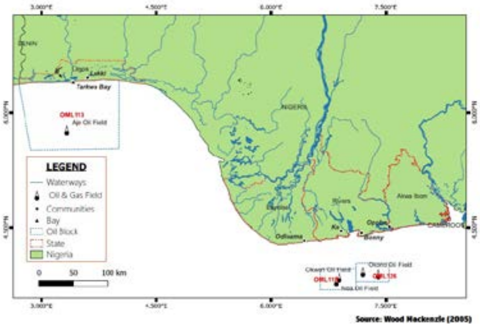

Fig. 1 The Combination of OML, 113, 119 and 126 Location Map

Source: Researchers Construction

There are three areas of study in this article. The first is the Aje oil and gas field (located 24 kilometres offshore of western Nigeria) adjacent to the border with Benin. Aje is the name of the riverine community where OML 113 is situated. The Aje field, which forms part of the OML 113 block (originally OPL 390), is located 24km from the coast of Nigeria and 64km from Lagos, with water depth varying from 99m to 1500m. Badagry Local Government Area of Lagos State (Fig. 1) is the host community of the Aje oil field seeing that it's the closest community and its environment is impacted by their operation. Badagry is the community between Lagos State and Benin Republic.

The second Study Area for this thesis is the OML 119 located in the southeastern Niger Delta (Fig 1.2) at Latitude / Longitude: 3.991252° / 7.290667°, approximately 50 kilometers offshore. The Okpoho and Okono Fields are located in Block OML 119 (former Block OPL 91), are 34 miles (55 km) from the Nigerian coast, in water depth ranging from 210 to 250 ft. (65 to 75 m).

The third Study Area for this thesis is the OML 126. This is a shallow water block in the Niger Delta. There are four fields on the block but only two - Okwori and Nda - are producing. Addax brought them on stream in 2005 via subsea wells tied-back to the leased Sendje Berge floating production, storage and offloading (FPSO) vessel.

V. LITERATURE REVIEW

Hazard is a condition, object, activity or event with the potential of causing injuries to people, damage to equipment or structures, loss of material, or reduction of ability to perform a prescribed function Ilias, *et al*, (2009). Ahmed, *et al*, (2012) defined hazard as the presence of materials or conditions that have the potential of causing loss or harm or a combination of the severity of consequences and likelihood of occurrence of undesired outcomes. Basically, a hazard is something that can cause harm or adverse effects such as to individuals as health effects, to the environment or to organizations as property or equipment damage. Some examples are: a lit cigarette, a wet floor, direct exposure to the sun, or exposure to toxic chemicals. According to Wester University (2012) hazard is anything (e.g. condition, situation, practice, behaviour) that has the potential to cause harm, including injury, disease, death, environmental, property and equipment damage. The term 'hazard' is used in many contexts. In a community context, for example, references are made to meteors, earthquakes and floods as 'natural hazards, ' golfers refer to 'playing the hazard' and hazard is sometimes used as a verb (e.g. to 'hazard a guess') (Safety Institute of Australia, 2012). In the view of International Labour Organization (ILO) hazard has been defined as the inherent potential to cause injury or damage to people's health (International Labour Organisation, 2011). While this conception is open to encompassing all types of hazard, the resultant vagueness makes it difficult to apply. Another commonly used definition that is arguably only slightly more conducive to operational application is the Standards Australia/Standards New Zealand (SA/SNZ) definition that refers to a hazard as: “a source or a situation with a potential for harm in terms of human injury or ill-health, damage to property, damage to the environment, or a combination of these” (Standards Australia, 2001). Similarly broad approach to hazard definition was adopted by Safe Work Australia in the 2010 draft code of practice developed to support implementation of the national Model Work Health and Safety Act:

> “Hazard means a situation or thing that has the potential to harm a person. Hazards at work may include: noisy machinery, a moving forklift, chemicals, electricity, working at heights, a repetitive job, bullying and violence, a badly designed workplace and inadequate management systems (for example, no procedures for performing tasks safely) (Safe work Australia, 2010).”

Hazard identification is the process of examining each work area and work task for the purpose of identifying all the hazards which are “inherent in the job”. Work areas include but are not limited to machine workshops, laboratories, office areas, agricultural and horticultural environments, stores and transport, maintenance and grounds, reprographics, and lecture theatres and teaching spaces. Tasks can include (but may not be limited to) using screen based equipment, audio and visual equipment, industrial equipment, hazardous substances and/or teaching/dealing with people, driving a vehicle, dealing with emergency situations, construction. This process is about finding what could cause harm in work task or area. According to Hubbard (2009), risk management is the identification, assessment prioritization and response, followed by coordinated and economical application of resources to minimize, monitor, and control the probability and impact of unfortunate events (accidents/risk) and to maximize the realization of goals, objective function and opportunities. A functional definition by Wilson & McCutcheon, (2003) of risk management describe risk management as the complete process of understanding risk, risk assessment, and decision making to ensure effective risk controls are in place and implemented. Risk management begins with actively identifying possible hazards leading to the ongoing management of those risks deemed to be acceptable. Risks represent significant vulnerabilities about outcomes.

A. *Occupational Injuries in Offshore*

Occupational injuries are definitely a common occurrence among workers on oil rigs. Based on the analysis of data from 518 workers on an American oil rig in the Mediterranean Sea between May 1998 and May 1999, Valentic, *et al* (2005) identified a number of occupational injuries and diseases among the workers. These data were the result of medical examinations of injured workers many of whom were Americans, British, Scots, Italians, Croatians, Bosnians, Albanians, Malteses and Indians. Of the 518 workers examined, occupational injuries were most frequent among the oil drillers (223), their assistants and manual workers at the drilling floor, rotating drill under the tower and around drilling tubes. Then followed injuries in deck hands and engineers (192) and auxiliary personnel (41), catering (36) and specialized services staff (26). However, no injuries were recorded among the management personnel. They also found that nearly 80% (414) of ill and injured workers were those engaged in the direct work process. This means that only those Ghanaians who will be directly involved in the extraction of the crude oil and gas will suffer most of the injuries.

Valentic, *et al* (2005) found that the workers suffered injuries ranging from contusion (bruise), cuts, laceration, alien body, chemical injury, thermal injury, luxation (joint dislocation), bone fracture, and amputation of phalanges of fingers or whole hand. Among the 138 injuries recorded by the medical officers at the oil rig hospitals, the top three occurring injuries among the workers were contusion, cuts, and laceration (wounds with irregular edges) respectively with luxation, fracture, and amputation rarely occurring. Valentic, *et al* (2005) also classified the injuries according to the part of the body involved in the injuries. They recorded hand and finger injuries, leg (without foot), and eye injuries. Others were head and neck, arm (without hand), foot and trunk injuries.

VI. METHODOLOGY

The survey research design was utilized for this study. The population for this study include all workers of Yinka Folawiyo FPSO Front Puffin OML 113, FPSO Mystras Nigerian Petroleum Development Company (NPDC) OML 119 and fpso Sendje Berge okwori field OML 126. According to HR Departments, the total number of workers at the FPSO locations is as follows; Yinka Folawiyo FPSO is 105, Mystras FPSO is 134 and Sendje Barge FPSO is 138. Total population in the study areas is 377 workers. The sample size of the study is 278 and it was arrived at with the use of Taro Yameni formulae. The research instrument used to collect primary data for this study was structured questionnaire. A total of 278 copies of the structured questionnaire were administered by the researcher and his research assistants.

VII. RESULTS AND DISCUSSIONS

The data collected, were analysed with suitable statistical tools that produced accurate results that can support authenticity and make the research findings usable, insightful and actionable. The combination of tables, chart and percentages.

Table 1: Distribution, Retrieval and Useful Questionnaire

Studied FPSO	No of distributed	Percentage %	No of retrieved	Percentage %	Useful	Perce
Yinka Folawiyo (OML 113)	80	28.8	75	27	69	25
Mystras (OML119)	97	34.9	92	33	81	29
Sendge (OML 126)	101	36.3	97	35	86	31
Totals	278	100	264	95	236	85

Source: Researchers Field survey, 2021

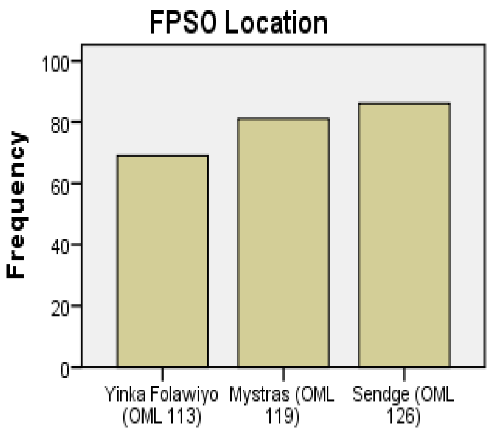

Fig.1: Showing Study Areas questionnaire distribution and retrieval

Fig. 1 Pictorial representation of data obtained from respective FPSO locations

The study research instrument was distributed to the staff of 3 selected companies. These details are provided in table 3.1 above. The details stipulate questionnaires distribution, retrieval and usefulness to the study according to the respective companies. Similarly, a total of 278 copies of questionnaire representing respondents of the 3 FPSO companies, 264 questionnaires were returned; I was unable to retrieve 14 questionnaires after several efforts. Out of the 264 questionnaires, 236 had valid responses, which were utilized for this analysis

Table 2. Evaluation of hazards peculiar to floating production, storage and offloading (FPSO) location.

S/N	Hazards Examination	Most unlikely	P value	Unlikely	P value	Likely	P value	Most likely	P value
1.	Noise hazards could lead to incident on your FPSO.	25	0.106	-	-	-	-	211	0.894
2.	Space constraint could lead to incident on your FPSO			91	0.386	141	0.597		
3.	Heat could lead to incident on your FPSO			83	0.352	153	0.648		
4.	More Frequent oil sampling could lead to incident on your FPSO	207	0.877			29	0.129		
5.	Rolling could lead to incident on the platform.	38	0.161					198	0.839
6.	Corrosion of equipment could lead to an incident.			21	0.089			215	0.911
7.	Slippery surfaces has been the major cause of hazard in your FPSO			35	0.148			201	0.851
8.	There is a high risk level associated with working at height in the FPSO	86	0.364			150	0.636		
9.	Confined space activities have been the prevalent cause of incidents in FPSO.			24	0.102			212	0.898
10.	Physical isolation has impact on hazard levels on the platform.	193	0.818			43	0.182		
11.	Equipment vibration has led to incidents in your FPSO			74	0.314	162	0.686		
12.	Frequent audible / loud alarm on the FPSO is a health hazard.	186	0.788			50	0.212		

Source: Researchers Field survey, 2021

The table.2 above stipulates responses on the possibility of occurrence of each hazard peculiar to FPSO in the offshore environment. From the table above there are four probabilistic aspects which responses are derived from, which include; most unlikely, unlikely, likely and most likely. Although, by probability we are to ascertain either of 2 options which is; the likelihood of occurrence or not. This then lead us to only focus on calculating the responses that indicate likelihood, while we negate the unlikely / most unlikely segment because in probability no occurrence signifies that the chances of such incidents happen is almost zero. Therefore, we relied mainly on the probability of incidents occurrence to ascertain the level of risk such hazard portend on the risk rating scale. But, the review of the level of severity of all incidents in categorizing the entire hazard related incidents before an overall estimation was done to propose an acceptable rating scale for offshore Risk. Meanwhile, the survey uncovered several types of hazards peculiar to the FPSOs operating the Nigerian offshore environment. All of these hazards were based on the extent of incidents experienced at the surveyed study areas.

A) Some Key Hazards Identified in FPSO's

Noise is the first hazard identified in this study that is associated with the FPSO environment. The findings from this study indicated that all 236 valid respondents agreed that FPSO operations is exposed to noise. Also, the source stated that the root cause sources of noise are Gas Flaring, Gas lift compressor operation, Power Generators and boiler exhaust flaring. On the item concerning the maximum noise level generated at the Offshore FPSO platform, it was revealed that the level of noise generated at the platform varies between as low as 80, 85, 89, 95.8, 101, 105.7, 110 to as high as 125 decibels. The picture below showed a pictorial representation of a voice generator.

Plate. 1 FPSO front puffin noise map
Source: Researchers Field survey, 2021

Similarly, the findings indicated that the 3 surveyed FPSOs have a noise map available and updated in their facility in order to know the noise level generated at every given point. See Fig. 2 for typical noise map from FPSO Front puffin. The red dots indicates areas with noise level above 85 decibels and green indicates areas with noise maps below 85 decibels. The responses obtain on the availability of ear protection kit indicated that the 3 surveyed FPSO's have it available in their facility.

B) Space constraint

The offshore location is mainly situated on the sea with the help of a prefab ship which provide the platform for crude oil processing operation. Meaning that the ship becomes the only solid surface provided to enable physical work activities to take place. This has now brought about the concern to ascertain if space constraint is a risk factor and to what extent it is to the offshore operation. The result from the survey revealed that the work space available to offshore workers is not adequately enough as revealed from the data in the questionnaire.

Plate 2**:** Space constraints on Engine room FPSO Front puffin
*Source***:** Researchers Field survey, 2021

C) Rolling on the FSPO

FPSO ships positioned and made to maintain a particular location on the sea with the help of an anchor used to sustain it at the four or more different point, except for turret FPSO's (like FPSO Front Puffin OML 113 Aje field). The result from the survey showed that, despite the anchor used in positioning the ship, the ship still experience frequent rolling in the direction of the wave. This rolling is measured in degrees, which at different times the maximum of rolling level could vary between 1^0, 2^0, 5^0, 9^0 and 10^0.

D) Heat

Heat is another issue associated with the FPSO at the offshore location. The survey result revealed that the sources of heat at the offshore location include Sun light Exposure, GDU Thyristor/Lean Glycol heater, crude processing heater device, live pipe line surfaces, gas flaring, emission from super structural surfaces (hand rails, decks, etc.) and in the accommodations when there is no air conditioning unit. Similarly, the findings from the survey showed that the protective devices used to avert the effect of heat on the FPSO's are cladding and insulation, hand gloves (PPE), "Hot Surface signage and stickers. The picture below show a typical

Plate 3**:** Heat due to gas flaring at FPSO
Source**:** Researchers Field survey, 2021

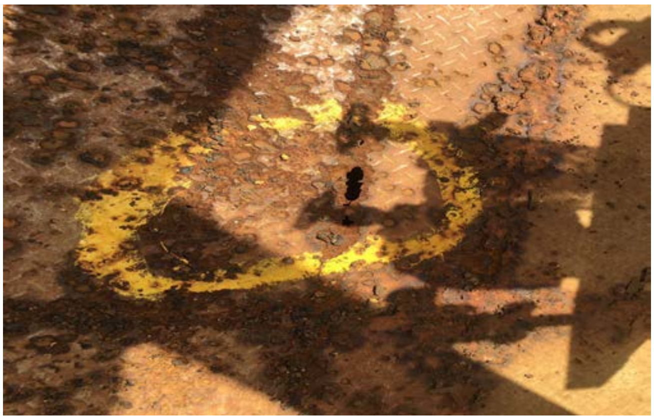

Plate 4: Corroded deck plate surfaces at FPSO front puffin
*Source***:** Researchers Field survey, 2021

E) Frequency of Crude Oil Sampling

The more regular crude oil sampling in FPSO is another concern when evaluating possible risk factors in an offshore environment. Result from the survey shows that crude oil sampling happens as much as 4 to 6 (six) times daily. The survey result further showed that the crude oil sampling material used in FPSO are either metal, plastic and glass sampling cans. Also metal buckets and glass measuring cylinders are used depending on the parameters to be analysed. Respondents unanimously stated that they are exposed to gas inhalation. Although, the control measures put in place to minimize gas inhalation include use of nose mask, positioning between directions of wind approach and keeping a safe distance from sampling spot.

F) Corrosion Level in the FPSO

The level of corrosion at the offshore location is another risk factor in an FPSO operation. The result from the survey indicated that all machineries used at the FPSO's are exposed to corrosion due to exposure to salty water. The findings showed that the measures put in place to control corrosion are injection of corrosion inhibitor into process streams and surface coating / painting, application of Grease on surfaces and wrapping surfaces with denso tapes.

G) Slippery surfaces

Slippery surfaces is another risk factor in an FPSO. The result from the survey showed that the cause of having a slippery deck surface is usually as a result of Rain, occasional minor lube oil or chemical spill and after every deck wash activities. In the quest to understand the control measure put in place, it was discovered that in some areas of the FPSO's anti-slip paint was used and some areas were left without anti-slip paints. No other control measures in place.

H) Work at height

Working at a high altitude is another risk factor in an FPSO operation. The experience gathered from the study indicated that the measures put in place during work at height are the use of scaffold and safety harnesses. During rolling periods, this operation can be aborted.

Plate 5: Working at height at FPSO front puffin
*Source***:** Researchers Field survey, 2021

I) Possible Solution on Best Practices Aimed at Addressing The Ills Associated with the Current Status of Occupational Hazards in the Operation Of FPSO.

Operating companies like FPSO's should practice holistic hazards and risk approach. This means to identify and evaluate all hazards and risks related to any offshore oil and gas operation to be wholly identified and understood. These risks may be operational, site and time specific. In a total field lifecycle perspective, from field development, engineering, construction, operations, modifications and decommissioning, the maintenance of a holistic risk overview is always a challenge. When taking into account the different field life stages and the number of parties involved, it is no less challenging. To ensure that risk management is approached in a holistic manner, access to tools that keeps up-to-date records of risk identification should be provided for all parties involved in the activities. This will provide a complete view of the risk exposures for an asset, asset cluster, project or company. This tool must consider major hazards that might lead to large hydrocarbon spills and loss of life, and also the risk of rare events that would have major consequences would also be addressed.

Also, there is need to ensure review on existing laws as to have strong penalties as to effectively criminalise breaches by operating companies. It becomes ridiculous when a fine of N2000 (less than £10) is imposed on anyone convicted of an offence of non-compliance as stipulated by the provisions of Part II of the Mineral Oils (Safety) Regulations 1997 intends to achieve as compared to the imposition of £2,000 by Section 33 of the HSWA 1974.

Another major hazard that needs urgent attention in the offshore during crude oil production is possibility of environmental pollution. The efforts of DPR to control pollution in the oil and gas industry and issuing EGASPIN must be commended. Though some of the provisions of the EGASPIN are commendable, the regulations to manage offshore (E&P) wastes in Nigeria cannot still be compared with the standard in many countries. In Nigeria, the current limit for the discharge of effluent including produced water into offshore water bodies is low.

The implication of hazard in an offshore operation has far reaching effect, both on the workers and on the equipment. Presence of Hazards and when triggered are capable of halting operations whenever they occur. This is why it becomes necessary to leverage on all possible ways of preventing its occurrence. All incidents reported showed a degree of negligence in adherence to safety measures and absence of adequate hazard identification and risk assessment model.

To achieve this, the researcher, based on field survey and interviews identified 12 major occupational hazards peculiar to the FPSO operation in Nigeria and each of these hazards have unique occurrence pattern which is akin to the nature of its workflow activities. From the hazard evaluation results, we derived that all hazards are not at same category after ratings. /

VIII. RECOMMENDATION

Operating locations like offshore FPSO's should practice holistic hazards and risk approach. This means to identify and evaluate all hazards and risks related to any offshore oil and gas operation to be wholly identified and understood. These risks will be operational, site and time specific. In a total field lifecycle perspective, from field development, engineering, construction, operations, modifications and decommissioning, the maintenance of a holistic risk overview is always a challenge. When taking into account the different field life stages and the number of parties involved, it is no less challenging. To ensure that risk management is approached in a holistic manner, access to tools that keeps up-to-date records of risk identification should be provided for all parties involved in the activities. This will provide a complete view of the risk exposures for an asset, asset cluster, project or company. This tool must consider major hazards that might lead to large hydrocarbon spills and loss of life, and also the risk of rare events that would have major consequences would also be addressed.

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IX. CONTRIBUTION TO KNOWLEDGE

The survey analysed 12 known major hazardous situations peculiar to FPSO operation in the offshore. Amongst the list are hazards like Noise, Space constraint, severe rolling of the FPSO, heat, frequent crude oil sampling, corrosion level, physical isolation, equipment vibration, frequent alarms, confined space, slippery surfaces and working at height. These hazards were observed and gathered during field survey at all the study areas. Also sources of noise can be, through gas flaring operations, gas lift compressor operations and power generators. This makes the noise pollution experienced at the offshore environment almost inevitable. Although, there is a noise map, which only help to communicate to all crew members the noise level within the FPSO, but cannot help in mitigating the effect.

The result from this survey showed that all the FPSO's surveyed have very minimal space provided for operations as shown in Plate 4.2. You can clearly see from the picture how machineries are installed very close to each, thereby making it difficult for maintenance to be carried out safely. Because of this constraint, some operations are suspended and carried out later. Also some activities like some category 1 hot work and threading of lengthy pipes are carried out ashore and then completed units are brought to the FPSO for installation. Space constraint has also led to carrying out certain activities offsite. Other consequences of space constraints includes heat (exhaustion due to awkward positioning during work), noise due to clustered machineries, difficulty in movements, decision to work offsite with scaffolding and injury to personnel due to possibility of body contact on rotating parts.

Another hazard in the FPSO operation is severe rolling. Since FPSO is where storage and crude oil production are carried out and usually experience, from the survey, between 1 to 40 degree levels of rolling which is mostly caused by the water tidal waves/current. The survey result stipulated that it is one of the critical causes of incidents which portend high severity to operation. Similarly, findings have also reported the adverse effect of rolling in the offshore environment. For example, Patel et al, (2019) in a study titled development of downtime cost calculation for offloading operations influence by parametric rolling, it was revealed that extreme weather and vessel motion response in side-by-side configuration can affect the offloading procedure. Parametric rolling is a potential threat to offloading operations due to sudden building of roll amplitude. The parametric roll is sudden enforced rolling movement of the floating body in the head or following sea-state resulting in dynamic rolling instability.

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