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FIRE RISK ASSESSMENT OF THE SEPARATION UNITS IN SELECTED OIL AND GAS COMPANIES IN RIVERS STATE

Ogbowu, E. N.,[1]
Ugwoha, E. [2]
Amah, V. [3]
Centre for Occupational Health, Safety and Environment (COHSE)
University of Port Harcourt, Rivers State, Nigeria
Email; estallaogbowu@gmail.com

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Abstract
This study focused on fire risk assessment of the separation units in selected oil and gas companies in Rivers State. Analytical and descriptive research designs were adopted. Separation unit which is among the most fire vulnerable units was considered in this study. Twelve fire-related hazards associated with the separation units were ascertain using Fire and Explosion Risk Assessment (FERA) (2020) guideline and the hazards were grouped into flammable sources and heat/ignition sources. The risk assessment was conducted by ranking of the hazards based on their risk score using Conventional Risk assessment (CRA) and Weighed Risk Assessment (WRA). The risk score of the fire-related hazards were evaluated using their severity and likelihood. The severity and likelihood of the hazards were determine using questionnaire administered to four hundred field-workers in three selected oil and gas firms in the study area and a predetermined factor (response weight) was assigned to field-workers based on their safety-related experience. The results revealed that fire-risk hazards in the separator unit were mostly classified under "High risk and Extreme risk" using Risk Assessment Matrix because their risk scores were greater than the 12.00 threshold for low risk hazard. The fault tree analysis (FTA) revealed that "Leakage of Hydrocarbon due to failure from high pressure flow" and "Failure of temperature controller" are unique fire-risk hazards with most devastating fire effect that must not be allowed to co-exist in the separation units. It was concluded that separation units of the oil and gas companies are high-to-extreme risk to fire accidents. It was therefore recommended that management of the oil and gas companies should pay a closer attention to the fire-safety of the separation units because it is one of most vulnerable unit to fire incident in the oil and gas companies

Keywords: Fire risk assessment, Separation Units, Oil and gas Companies, Rivers State.

1. Introduction

The main objective of occupational safety and health (OSH) risk management in the oil and gas industry is to identify and assess potential hazards and risks to workers' health and safety, and to implement controls to prevent or minimize these risks (Oppong, 2011). This is done to ensure that workers are able to work in a safe and healthy environment, and to reduce the likelihood of accidents, injuries, and illnesses. The OSH risk management process in the oil and gas industry typically involves several steps, including hazard identification, risk assessment, risk prioritization, risk control, and ongoing monitoring and evaluation

(Oppong, 2011). This process is designed to systematically identify and address hazards and risks in the workplace, and to ensure that appropriate controls are in place to mitigate these risks. The ultimate goal of OSH risk management in the oil and gas industry is to create a culture of safety and health in which workers are empowered to identify and report hazards, and to actively participate in the development and implementation of safety and health programs. By promoting a proactive approach to safety and health, companies in the oil and gas industry can reduce the likelihood of accidents and injuries and ensure that workers are able to work in a safe and healthy environment (International labour Organization (ILO, 2013)

Currently, the oil and gas industry are facing massive pressure to prioritize Health, Safety, and Environmental (HSE) risk management as a crucial aspect of their daily operations (Badrul, 2015). The stakeholders in the industry, including workers, governments, and communities, are demanding world-class performance and operational excellence to prevent accidents and minimize the impact of any misfortune such as fire accidents and oil spill. The industry also faces a shortage of technical specialists and an aging workforce, and the demand for petroleum engineers with HSE focus is expected to increase. As the industry continues to prioritize HSE, it will create awareness and a safety culture to improve the health and safety of its workers and the environment. Environmental Health Safety professionals play a critical role in ensuring the safety of workers and the public in various industries. They analyze risks and provide recommendations for managing dangers while adhering to regulations (Faith, 2014)

Fire risk assessment adopts a systematic approach to identify potential fire threats and evaluate their potential consequences upon occurrence. In the current fiercely competitive oil and gas business landscape, conducting fire risk assessments in the oil and gas industries has become a challenging endeavor due to the inherent uncertainty and imprecision associated with fire risks. Widely used to facilitate fire risk mitigation, prevention, and maintenance, fire risk assessment plays a crucial role in identifying, quantifying, and evaluating unwanted fire-related hazards within the oil and gas industry. This process involves categorizing and measuring the outcomes related to fire risk in a specific incident and under particular scenarios. These incidents may encompass personal burn injuries to workers, releasing of soot from incomplete combustion of crude oil which could cause air pollution as well as burning of oil and gas drilling, production, processing or storage assets, all of which can significantly impact the reputation and operation of the industry (Bigliani, 2013; Hussin et al 2016; Zardasti 2017)

For proper execution of a fire risk assessment, it is essential to utilize a suitable risk matrix for evaluating the fire risk level associated with hazards. The risk matrix, a conventional method for conducting risk assessments, serves as a valuable tool in this process. Typically, it aids in pinpointing the most critical risks and offers a methodology for evaluating the potential impacts associated with each risk. The risk matrix proves advantageous in identifying risks by combining the likelihood and severity of consequences resulting from the occurrence of hazards (Ikwan et al, 2021; Trbojevic & Carr, 2010). According to Altenbach (2010) the efficacy of a decision is significantly contingent on both the input data and the methodologies employed for analyzing that data. The process of fire risk assessment generally revolves around three main steps, identification of fire risk hazard, analyzing the fire risk and evaluating the fire risk hazard. (Cox, 2006). These could be carried out using either, qualitative, semi-qualitative or quantitative risk assessment techniques.

According to Modarres (2006), the qualitative risk assessment technique involves assessing compliance with certain relative decisions to classify potential hazards. This method relies on subjective judgment, prioritizing expert opinions. Rather than using quantified values, descriptive terms such as "likely," "unlikely," and "most probable" are employed to describe failure probability and consequences. For instance, levels like low, moderate, and high are used for consequence assessment. The semi-quantitative risk assessment technique is used to categorize critical equipment or components, and final risk scores are determined through various methods, in the context of semi-quantitative. Radu (2005) explains that the semi-quantitative risk assessment technique serves as an intermediary between the subjective evaluation of qualitative risk assessment and the numerical evaluation of quantitative risk assessment. This approach evaluates risks using a score based on estimated numerical values for failure probability and consequence. Likewise, Mearns and Flin (2005) highlights the quantitative approach, which involves assessing risk through numerical simulation, incorporating a quantitative calculation of possibilities and consequences for various accidents. Typically, the outcomes of the quantitative method yield individual risk assessments.

In the oil and gas industry, risk assessment is a pivotal factor in determining the hazard risk level. In the realm of the oil and gas industry, risk assessment and decision making have been considered as a critical factor in the industry. The investigation of risk assessment factors assists the decision-maker in the industry in minimizing risk-related issues and making the appropriate risk decisions (Dahmani et al., 2020; Yang & Haugen (2015). The oil and gas sector are saddled with the responsibility of production, processing, transportation, storage and distribution of petroleum and its derivatives from the oil wells to the final consumers. Petroleum and its derivatives are hydrocarbon mixtures that are highly flammable substances. hence, there is high propensity of fire accidents along the production, processing and distribution chain of petroleum and its derivatives (Danzi et al., 2021). Based on these aforementioned problems, there is need to carry out regular fire risk assessment along the production, processing and distribution chain of petroleum and its derivatives in order to prevent possible fire accidents. Thus, this current study is carried out as solution to the problem which is basically to design a fire risk assessment model and investigate fire risk possibilities in compression and separation units of oil and gas firms operating in Rivers State. Hence, the aims of the study are to; one, determine the fire risk level of the compression and separation units in the selected oil and gas companies in Rivers State. and two, develop fire risk assessment models for the separation units in the selected oil and gas companies in Rivers State

2. Methodology

2.1 Research design

This study adopted analytical descriptive research design. Analytical design was used to carry out a robust fire risk assessment of separation units in the sampled oil and gas companies in Rivers State using Risk Assessment Matrix (RAM) and Fault Tree Analysis (FTA) for oil and gas companies in Rivers State.

2.2 Study area

Rivers State is a state in the Niger Delta region of southern Nigeria, formed in 1967, when it was split from the former Eastern Region, Rivers State borders includes; Anambra and Imo on the north, Abia and Akwa Ibom on the eastern part and Bayelsa and Delta on the west. The state capital, Port Harcourt, is a metropolis that is considered to be the commercial centre of the Nigerian oil industry. With a population of 5,198,716 as of the 2006 census, Rivers State is the 6th most populous state in Nigeria. Rivers State is a diverse state that is home to many ethnic groups, the majority being Igbo, but also including the Ogoni and Ijaw. The state is particularly noted for its linguistic diversity, with 28 indigenous languages being said to be spoken in Rivers State, dominant of which, are the Igbo speaking groups, the Ogoni and Ijaw languages. Rivers State has a total area of 11,077 km^2 (4,277 sq mi) making it the 26th largest state by area and its geography is dominated by the numerous rivers that flow through it, including the Bonny River. Figure 1 is the map of the Rivers State showing the location of the three oil and gas companies sampled in this study while Table 1 show their various coordinates. The map revealed that the coordinate of the Chevron Oil and Gas are 7° 2' 1.5" E and 4° 50' 4.0" N, coordinate of Moni Polu Limited are 7° 0' 34.6" E and 4° 47' 28.3" N while that of SEPLAT are 7° 2' 13.1" E and 4° 48' 4.0" N

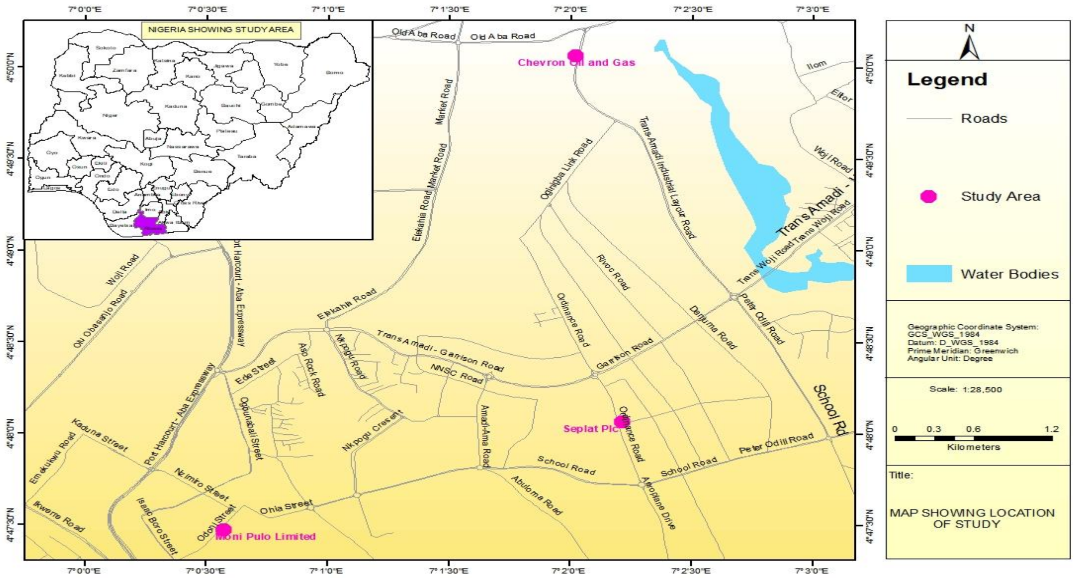

Figure 1 Map of River State showing the location of the three sampled oil and gas companies.

2.3 Population and sampling technique of the Study

This study was concerned with fire risk assessment and emergency procedure for loss prevention in selected oil and gas firms in Rivers State, Nigeria, therefore, the population of this study comprised of field workers of the sampled oil and gas companies operating in River State. There are one hundred and ninety-five registered oil and gas companies in Rivers state according to DPR, however, only twenty-eight (28) are involved in oil and gas exploration and production. Out of the twenty-eight, three have separation units required for this study and these three were purposively sampled, and population of the workers totaled at one thousand three hundred and twenty-six (1326) according to their human resource department

2.4 Sample Size Determination

The sample size of the respondents in this study was determined using the Taro Yamane sample size determination formula. expressed in Equation (1)

$$n = \frac{N}{(1+N)(\varepsilon)^2)} \quad (1)$$

Where n = Sample size, N = Population under study and ε = Margin error (which is 5% level of significance respectively). Hence, for the international oil and gas companies, the sample size is calculated as

$$n = \frac{1326}{(1+1326)(0.05)^2)}$$

n = 400,

Thus, the sample size for field workers in the oil and gas companies is 400. This sample size was distributed among the company based on the proportion of their population. Table 1 shows the distribution of the sample size among the various field workers in the various sampled companies.

Table 1 Distribution of the sample size among the field workers

S/N	Companies	Sample				
		HSE Officers	Field Managers	field Supervisors	field Engineers	**Total**
1	Company A	10	10	15	52	**87**
2	Company B	10	10	15	59	**94**
3	Company C	20	25	40	134	**219**
	Total	**40**	**45**	**70**	**245**	**400**

However, the respondents in this study are the main field workers who are directly involved in the major operations of the various units including the separation unit and also concerned with the safety of unite operations in the oil and gas firms sampled. They include:

1. Health-safety and Environment (HSE) Officers (HSEO)
2. Field Operation Managers. (FOM)
3. Field Operation Supervisors (FOS)
4. Field Engineers/ Workers (FE/O)

These four groups of field workers are respondent because the safety and operation of the various operation unit is directly or indirectly their responsibility. Based on their hierarchy and experiences they were designated at Expert 1(EX_1), Expert 2(EX_2), Expert 3(EX_3) and Expert 4(EX_4) respectively. Because of different experience of these workers, their responses were weight based on fraction assigned to them, such that workers of high rank which signifies higher experience are assigned higher weight see Table 2. The weighted factor or response weight is evaluated as:

$$RW = 1 + \frac{assigned\ number}{summation\ of\ all\ the\ assigned\ number} \quad (2)$$

For instance, since we have four categories, the assigned number based on ranking or experience is 4, 3, 2 and 1. Hence, the response weight of most ranked grouped or most experience group whose assigned number is 4 is given as

$$RW = 1 + \frac{4}{4+3+2+1}$$

RW = 1.4, hence for group assigned 3, RW = 1.3 for group 2 RW = 1.2 and group 1 = 1.1 (Akpan et al., 2020)

Table 2 Distribution of the respondents in the Various Ranks and their various response Weight.

The workers	Expert 1	Expert 2,	Expert 3,	Expert 4.
Position	HSE Officer	Field Managers	Field Supervisors	Field Engineers
Response Weight	1.4	1.3	1.2	1.1

Source: Akpan et al. (2022)

2.4.1 Sampling of Unit process for fire Risk Assessment

The process plant of a fully manned production facility typically includes a number of stages of oil, gas and water separation, gas compression and dehydration processes. The risk present in the process plant is very high. Process plant can be a potential site for ‘Fire & Explosion. The risk due to fire and explosion in the process facility consist of more than 60% of the total risk of the overall installations. The process plant consists of many types of process units such as power plant, Separators, Compressors, Pumps and Pipelines. (NFSA, 2018). However, only the separation units were considered in this study,

2.5 Nature and Source of Data

Both primary and secondary data were used in this study. The secondary data was the documented fire hazards and different unit operations from the sampled oil and gas companies while the primary data was response of the field workers that were obtained using well-structured questionnaires that were distributed to the sampled workers in the oil and gas companies. The Checklist as used to identify the compression and separation unit operation among the high likelihood of fire and explosions and their corresponding hazards while the questionnaires were used to ascertain the information on for risk assessment specifically the likelihood and Severity of the hazards. The risk assessment was carried out using Risk assessment matrix (RAM) and Fault Tree Analysis (FTA).

2,6 Methods of Data Collection

Data were collected based on the availability of the field workers sampled. The purpose of the study was explained to these eligible participants. The study questionnaires were administered to them on the days of data collection. The questionnaires were self-administered. All duly completed questionnaires were retrieved on the spot and cross-checked for completeness. Due to size and type of the sampled respondent, the researcher used a research assistant to administer the questionnaire.

2.7 Instrument for Data Collection

A closed ended, modified 5-point Likert scaled questionnaire and a checklist was used in this study because this study requires a specific answer to questions that was designed to elicit information from the respondent on scaled questions designed to obtain the degree or level of the respondent’s opinion toward a quantified answer. Thus, the respondents are not given the room to freely express their opinion on the subjects of the questions rather they are only allowed to present their opinion based on degree or level of their experience and information towards the subject of the questions as was presented to them by the researcher. The modified 5-point Likert scale questionnaire was comprised of two sections: A and B; these sections were used to obtain response on the Risk assessment of the hazards associated with the two units sampled namely Separators and Compressors based on Likelihood and severity of fire and explosion occurrence in these units.

Note, for risk assessment data, there were two sub-sections for each of the main sectioned 1 and 2, each subsection was used to obtain data on Likelihood and Severity of the fire related hazards associated with the separation unit operations. See Table 3 for the modified five-point Likert scale and their meanings for Likelihood and severity.

Table 3 Assessment of Likelihood of the hazard

Likelihood terms	Severity Terms	Scale Value
Rare	Negligible	1
Unlikely	Minor	2
Possible	Moderate	3
Likely	Major	4
Almost Certain	Catastrophic	5

Source: NFSA, (2018)

Risk Assessment Matrix (RAM); Risk assessment matrix is based on evaluating the risk level of the identified hazards based on their severity and likelihood and then using the risk level to rank the hazards based on the position in their risk level in a standard risk assessment matrix. The risk score or level of the hazard is based on the product of the Severity of the hazard and their likelihood of occurrence, given as

$$\boldsymbol{Risk\ Level\ (RL)\ or\ Risk\ Score\ (RC)\ =\ Severity\ (S)\ \times\ Likelihood\ (L)} \quad (4)$$

The severity and likelihood of the various hazards associated with the various operation unit sampled was obtained using questionnaire design and administered to the four different categories of workers in the oil and gas firms sampled and assumed fraction of one was assigned to each group of categories of workers based on their experience and hierarchy in the field as relates to safety. This response weights were introduced to acknowledge the variation in exposure and experience of the various categories as regards to access to safety-related information in the oil and gas field, thus response from categories of workers with the highest safety related experience and access to safety-related information were given more response weight compare to less experience workers see Table 2

The conventional risk score is obtained by multiplying the severity score and the likelihood score without factoring the response weight of the various categories involved in the assessment. This kind of risk assessment presumed that all the respondents in the various categories have equal safety-related experience and access to safety-related information, which means that

$$\boldsymbol{Conventional\ Risk\ Level\ (CRL)\ =\ Severity\ (S)\ \times\ Likelihood\ (L)} \quad (5)$$

The weight risk level is obtained by multiplying the severity score and likelihood score as well as response weight of the respondent. This risk assessment takes due consideration of the fact that the respondent in different categories have different level of safety-related experience and access to safety-related information. Therefore, categories of respondent with higher safety-related experienced are given high response weight than categories with lower safety-related experienced respondent. Thus, the weighted risk level is evaluated as;

$$\boldsymbol{Weight\ Risk\ Level\ (WRL)\ =\ Severity\ (S)\ \times\ Likelihood\ (L) \times\ Response\ Weight\ (RW)} \quad \textbf{(6)}$$

Both the conventional and weight risk level were considered in this study to determine the difference between the two risk assessment models. The checklist was used to identify the unit available in the oil and gas companies and the probability of fire accidents in the unit. The probability of fire accident is determined by physically assessing the availability of flammables and combustibles in the unit and chance of heat or spark.

2.8 Methods and instrument of Data Analysis

The fire risk assessment data were analyzed in four different stages, which were expressed as Stage One, Stage Two, Stage Three and Stage Four;

Stage One: this stage involved using checklist and literatures on fire risk assessment in oil and gas firms to identify the most vulnerable and fire-accident prone units. Based on NFSA (2018), and the results of the checklist, Only the separation unit process operations are the sampled among the fire-prone units

Stage Two: this stage involves identifying the fire-related hazards in these process unit operations selected in stage one

Stage Three: the data obtained from the respondent on the likelihood and severity of the fire-related hazard effects for each of the units were used to evaluate the risk level of the hazards and these risk levels were ranked using Risk Assessment Matrix.

Stage Four: The risk levels obtained based on ranking using Risk Assessment Matrix were used to design of the Fault Tree based on Fault Tree Analysis (FTA) model and also to determine the riskiest route to the top event (fire or explosion in the unit operation). See Figure 2. In this study, the data on fire risk assessment was analyzed using the RAM and FTA flow chart see Table 4 for typical Risk Assessment Matrix

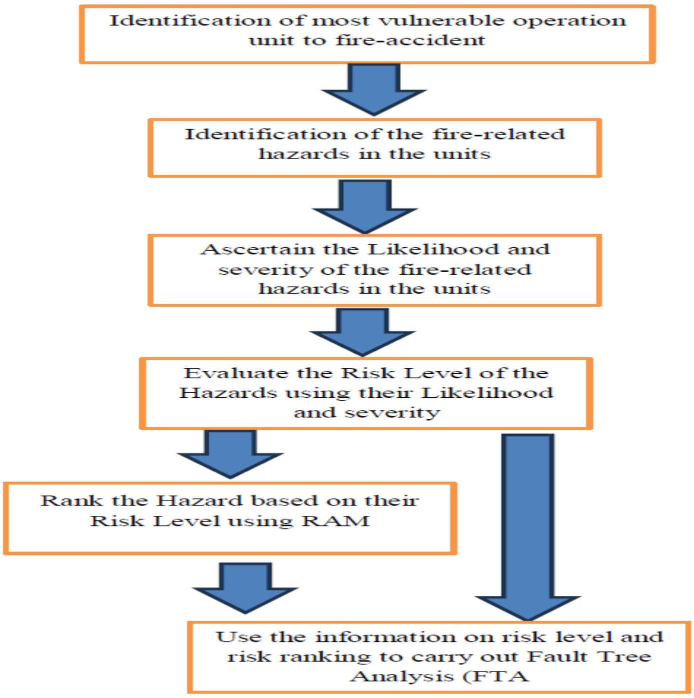

Figure 2: Flow-chart of the Propose Risk Assessment Procedure (Source; Researcher)

Table 4 A Typical Risk Assessment Matrix showing the various Risk level and Color Bandings

	Likelihood				
Consequence	1	2	3	4	5
	Rare	Unlikely	Possible	Likely	Almost certain
5 Catastrophic	5	10	15	20	25
4 Major	4	8	12	16	20
3 Moderate	3	6	9	12	15
2 Minor	2	4	6	8	10
1 Negligible	1	2	3	4	5

Source National Fire Protection Association, (2018).

For risk grading, the scores obtained from the risk matrix are assigned and graded as follows:

1–3	Low risk
4–6	Moderate risk
8–12	High risk
15–25	Extreme risk

Source National Fire Protection Association, 2018)

3. Results and Discussions

3.1 Risk assessment of the Separation Unit

The conventional risk scores of the various hazards associated with the separation units were evaluated from the response of respondent on the severity and likelihood of the hazard to cause fire and explosion accident during separation. The risk scores were evaluated separately for the four categories of workers as shown in Table5 to 8 while Table9 and 10 showed the overall conventional and weighted risk score for fire risk assessment for the separation units respectively. the arrangement on the hazard in Table 9 and 10 is such that the twelve (12) hazard involved are represented with 1 to 12 respectively

From the fire triangle model, three major factors are required to trigger fire and explosion incidences, flammable or combustible source, heat or spark sour and air or oxygen supply. Air or oxygen is readily available; therefore, fire risk assessment is usually based on combination of flammable or combustible sources and heat or spark source. In the separation unit, the fire risk assessment is based on twelve identified hazards that are related to flammable or combustible material and heat or spark source. In this study, the first six hazards (1-6) were based on availability of flammable sources while the last six (7-12) were focused on heat and spark source. Table 5 shows the response of the first category of experts on the severity and likelihood of fire accident in the separator units as well as the corresponding risk level of the various hazards. On the availability of flammable sources, the results revealed that "Leakage of Hydrocarbon due to Level indicator failed" with risk score of 19.23 is the riskiest hazard while "Temperature controller failed" with risk score of 14.55 is the riskiest hazard in terms of heat sources. Table 6 shows the response of the second category of experts on the severity and likelihood of fire accident in the separator units as well as the corresponding risk level of the various hazards. On the availability of flammable sources, the results revealed that "Leakage of Hydrocarbon due to failure from high pressure flow" with risk score of 19.64 is the riskiest hazard while "Temperature controller failed" with risk score of 16.60is the riskiest hazard in terms of heat sources.

Table 7 shows the response of the third category of experts on the severity and likelihood of fire accident in the separator units as well as the corresponding risk level of the various hazards. On the availability of flammable sources, the results revealed that "Leakage of Hydrocarbon due to failure from high pressure flow" with risk score of 18.60 is the riskiest hazard while "Temperature controller failed" with risk score of 15.60is the riskiest hazard in terms of heat sources. Table 8 shows the response of the fourth and last category of experts on the severity and likelihood of fire accident in the separator units as well as the corresponding risk level of the various hazards. On the availability of flammable sources, the results revealed that "Leakage of Hydrocarbon due to failure from high pressure flow" with risk score of 17.70 is the riskiest hazard while "Ignition due to explosion energy" with risk score of 16.73 is the riskiest hazard in terms of heat sources.

Table 9 shows the overall conventional fire risk assessment of the separator unit based on combination of the risk assessment of the four categories. The results revealed that; On the availability of flammable sources, "Leakage of Hydrocarbon due to failure from high pressure flow" with risk score of 18.46 is the riskiest hazard while "Temperature controller failed" with risk score of 15.33 is the riskiest hazard in terms of heat sources. Analysis of variance carried to ascertain whether there is a statistically significant difference in the fire risk assessment of the four categories of workers revealed that there is no statistically significant difference in the fire risk assessment of the four categories of workers on the first four hazards on availability of flammable sources with their p-values greater than 0.05 significance levels while there is statistically significance difference in their fire risk assessment for the last two hazards based on availability of flammable source with their p-values less than 0.05 significance level. On the available of heat source, the ANOVA results showed that there is no significant difference in fire risk assessment of the different categories in hazard number 7, 9, 11 and 12 as their p-values are greater than 0.05 significance level while statistically significance difference was observed in hazard 8 and 10 since their various p-value is less than 0.05 significance level.

Table 10 shows the overall weighted fire risk assessment of the separator unit based on combination of the risk assessment of the four categories. The results revealed that; On the availability of flammable sources, "Leakage of Hydrocarbon due to failure from high pressure flow" with risk score of 22.94 is the riskiest hazard while "Temperature controller failed" with risk score of 19.18 is the riskiest hazard in terms of heat sources. Analysis of variance (ANOVA) carried to ascertain whether there is a statistically significant difference in the fire risk assessment of the four categories of workers revealed that there is statistically significant difference in the fire risk assessment of the four categories of workers on the all the six hazards on availability of flammable sources with their p-values less than 0.05 significance levels. On the available of heat source, the ANOVA results showed that there is significant difference in fire risk assessment of the different categories in all the hazard as their p-values are less than 0.05 significance level except for hazard number 7 and 11 which showed no statistically significance difference as its p-value is greater than 0.05 significance level.

Finally, comparing the conventional and weighted risk score of all the twelves (12) hazards considered for the separation unit with the standard risk assessment matrix (RAM) in Table 4.10 revealed that the hazards are between high risk to extremely risky hazards. This is because the hazard considered had conventional risk score that ranged from 13.41 to 18.46 and weighted risk score that ranged from 17.15 to 22.94.

Table 5 Fire risk assessment based on expert one (1) respondents on the separation Unit

S/n	Hazards	Mean severity score (n=30)	Mean likelihood Score (n=30)	Mean Risk Score	Remark
1	Leakage of Hydrocarbon due to failure from high pressure flow,	3.85	4.65	17.90	Extreme risk
2	Leakage of Hydrocarbon due to Safety valve undersized	3.95	4.18	16.50	Extreme risk
3	Leakage of Hydrocarbon due to Safety / pressure valve failed	4.28	3.95	16.90,	Extreme risk
4	Leakage of Hydrocarbon due to Level indicator failed	4.01	4.80	19.23	Extreme risk
5	Leakage of Hydrocarbon due to corrosion of the separator chamber	3.83	4.49	17.27	Extreme risk
6	Leakage of Hydrocarbon due to Flow control valve failed	4.52	3.68	16.64	Extreme risk
7	Electric spark due to faulty electric appliance.	3.45	4.02	13.90,	High risk
8	Hot work around the separator like wielding.	3.08	4.18	12.90,	High risk
9	Ignition from vehicle sparkplug	3.35	3.68	12.36	High risk
10	Bush burning around the separator unit	3.25	4.27	13.90	High risk
11	Ignition due to explosion energy	3.24	4.37	14.18,	High risk
12	Temperature controller failed	3.28	4.43	14.55	High risk

Table 6 Fire risk assessment based on expert two (2) respondents on the separation Unit

S/n	Hazards	Mean severity score (n-35)	Mean likelihood Score (n-35)	Mean Risk Score	Remark
1	Leakage of Hydrocarbon due to failure from high pressure flow,	4.73	4.15	19.64,	Extreme risk
2	Leakage of Hydrocarbon due to Safety valve undersized	4.44	4.04	17.95	Extreme risk
3	Leakage of Hydrocarbon due to Safety / pressure valve failed	3.92	3.90	15.30	Extreme risk
4	Leakage of Hydrocarbon due to Level indicator failed	4.10	4.04	16.60	Extreme risk
5	Leakage of Hydrocarbon due to corrosion of the separator chamber	3.69	4.48	16.55,	Extreme risk
6	Leakage of Hydrocarbon due to Flow control valve failed	4.70	3.35	15.75	Extreme risk
7	Electric spark due to faulty electric appliance.	3.69	4.10	15.15	High risk
8	Hot work around the separator like wielding.	4.03	3.56	14.35	High risk
9	Ignition from vehicle sparkplug	3.88	3.37	13.10	High risk
10	Bush burning around the separator unit	3.87	3.27	12.65	High risk
11	Ignition due to explosion energy	4.18	3.68	15.40	High risk
12	Temperature controller failed	3.75	4.43	16.60	High risk

Table 7 Fire risk assessment based on expert three (3) respondents on the separation Unit

s/n	Hazards	Mean severity score (n-55)	Mean likelihood Score (n-55)	Mean Risk Score	Remark
1	Leakage of Hydrocarbon due to failure from high pressure flow,	4.03	4.62	18.60,	Extreme risk
2	Leakage of Hydrocarbon due to Safety valve undersized	4.40	3.69	16.25	Extreme risk
3	Leakage of Hydrocarbon due to Safety / pressure valve failed	3.82	4.33	16.55	Extreme risk
4	Leakage of Hydrocarbon due to Level indicator failed	4.10	4.32	17.72	Extreme risk
5	Leakage of Hydrocarbon due to corrosion of the separator chamber	3.19	4.87	15.55,	Extreme risk
6	Leakage of Hydrocarbon due to Flow control valve failed	4.20	3.87	16.27	Extreme risk
7	Electric spark due to faulty electric appliance.	3.92	3.66	14.36,	High risk
8	Hot work around the separator like wielding.	4.03	3.18	12.82,	High risk
9	Ignition from vehicle sparkplug	3.80	3.87	14.73,	High risk
10	Bush burning around the separator unit	3.85	4.04	15.55,	High risk
11	Ignition due to explosion energy	4.05	3.59	14.55	High risk
12	Temperature controller failed	3.70	4.21	15.60,	Extreme risk

Table 8 Fire risk assessment based on expert four (4) respondents on the separation Unit

s/n	Hazards	Mean severity score (n-220)	Mean likelihood Score (n-220)	Mean Risk Score	Remark
1	Leakage of Hydrocarbon due to failure from high pressure flow,	4.13	4.28	17.70	Extreme risk
2	Leakage of Hydrocarbon due to Safety valve undersized	4.10	4.04	16.55	Extreme risk
3	Leakage of Hydrocarbon due to Safety / pressure valve failed	3.80	4.56	17.35	Extreme risk
4	Leakage of Hydrocarbon due to Level indicator failed	4.25	3.59	15.27	Extreme risk
5	Leakage of Hydrocarbon due to corrosion of the separator chamber	3.55	3.85	13.65	High risk
6	Leakage of Hydrocarbon due to Flow control valve failed	4.32	3.14	13.55	High risk
7	Electric spark due to faulty electric appliance.	3.90	4.03	15.73	Extreme risk
8	Hot work around the separator like wielding.	4.35	3.72	16.18	Extreme risk
9	Ignition from vehicle sparkplug	3.85	3.96	15.27	Extreme risk
10	Bush burning around the separator unit	3.80	3.04	11.55	High risk
11	Ignition due to explosion energy	4.15	4.03	16.73	Extreme risk
12	Temperature controller failed	3.75	3.89	14.60,	High risk

Table 9 Conventional Risk Assessment Results for the separation unit

Hazards	Average Risk Score EX1	Average Risk Score EX2	Average Risk Score EX3	Average Risk Score EX4	Overall average Risk score	Ranking	p-value of ANOVA
1	17.90	19.64,	18.60,	17.70	18.46	1st	0.132
2	16.50	17.95	16.25	16.55	16.81	3rd	0.220
3	16.90,	15.30	16.55	17.35	16.53	4th	0.251
4	19.23	16.60	17.72	15.27	17.21	2nd	0.438
5	17.27	16.55,	15.55,	13.65	15.76	5th	**0.035**
6	16.64	15.75	16.27	13.55	15.55	6th	**0.045**
7	13.90,	15.15	14.36,	15.73	14.79	2nd	0.143
8	12.90,	14.35	12.82,	16.18	14.06	5th	**0.015**
9	14.18,	13.10	14.73,	15.27	14.32	4th	0.225
10	13.90	12.65	15.55,	11.55	13.41	6th	**0.020**
11	12.36	15.40	14.55	16.73	14.76	3rd	0.052
12	14.55	16.60,	15.60	14.60,	15.33	1st	0.335

Table 10 Weighed risk assessment for the separation unit

Hazards	Average Risk Score EX1	Average Risk Score EX2	Average Risk Score EX3	Average Risk Score EX4	Overall average Risk score	Ranking	p-Value of ANOVA
1	25.00	25.00,	22.32,	19.47	22.94	1st	**0.032**
2	23.10	23.34	19.50	18.20	21.00	3rd	**0.022**
3	23.66,	19.89	19.86	19.09	20.63	4th	**0.021**
4	25.00	21.58	20.66	16.80	21.01	2nd	**0.048**
5	24,18	21,52	18.66,	15.02	19.85	5th	**0.035**
6	23,30	20.48	19.52	14.91	19.55	6th	**0.005**
7	19.50,	19.70	17.23,	17.30	18.43	2nd	0.143
8	18.06,	18.65	15.38,	17.80	17.47	5th	**0.015**
9	19.85,	17.03	17.68,	16.80	17.84	4th	**0.045**
10	19.50	16.45	18.66,	13.98	17.15	6th	**0.020**
11	17.36	20.02	17.46	18.40	18.31	3rd	0.152
12	20.37	21.58,	18.72	16.06,	19.18	1st	**0.015**

These risk score and risk hierarchy associated with the hazards in the separator unit are similar to those reported by Hassan et al (2018) who in their work on Fire Hazards & Risk Assessment in Offshore Petroleum Facilities identified separator unit, compressor unit, pump unit and pipeline unit however, there is differences in risk score and risk hierarchy associated with the hazards separation unit. This could be attributed to the fact that the study carried out by Hassan et al. (2018) was done in Malaysia, therefore, it is expected that what could be considered as severe and likely hazards in Nigerian terrain may not be considered as severe and likely hazard in Malaysia for instance the issue of bush burning is a serious hazard common in Nigeria but it may not be a serious concern in Malaysia.

3.2 Fault Tree fire risk assessment model for separation units in the selected oil and gas companies in Rivers State

Figure 3 shows the fault tree diagram design to show the schematic representation of the chain of events in the analyzed separation unit which is designed using AND gate and OR gas to link the events and logical gate configurations. The probability of the top-level which is the fire accident in the separator unit can be determined by linking the hazards connected to the AND gate and OR gate using from the bottom of the tree to the top even which represent the fire accident in the separator. Table 9 and table 10 showed the conventional and weighted risk scores of the various hazards associated to fire risk in separation unit and it revealed that hazard 1 is riskiest flammable source and hazard 12 is most risk ignition source for fire risk. The riskiest hazard on both flammable source and heat/ignition source are shaded red in the fault tree which means that FTA shows that combination of those two hazard will generate the most catastrophic fire accident in the unit

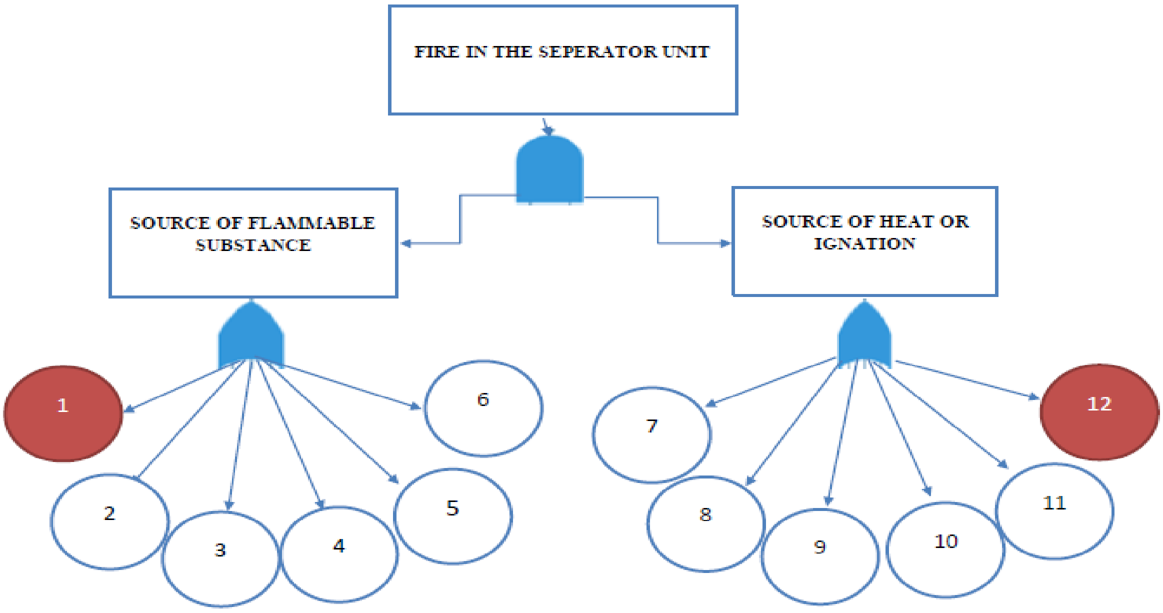

Figure 3: Fault tree Diagram of the Fire risk assessment of separation unit of the sampled Oil and gas firms

The outcome of this study aligned with work of Jozi et al. (20 12) who worked on "Quantitative fault tree analysis for urban water infrastructure flooding" in which they applied probabilistic FTA to evaluate the probability of urban water infrastructure flooding as a result of a range of causes, similarly Jozi et al. (2014) also used FTA to estimate the overall reliability of sprinkler systems in high-rise office buildings in Australia by using data from 26 projects in their work titled, "Reliability of sprinkler system in Australian high rise office buildings" Chang et al. (2012) in their empirical work titled "Failure mode and effects analysis using a group-based evidential reasoning approach" in which they applied FTA to analyses the failure of the soil nailing system and cement–soil retaining wall. They used the historical data of 342 actual excavation accidents in China to obtain frequency distributions of different accident causes and estimating the value of the Top Event. The study also aligned with findings of Khan et al (2004) who applied fuzzy FTA to analyse the failure of structures. As an example, the failure of the railing of a scaffold, which led to an accident, was discussed. Ardeshir et al. (2014) applied fuzzy FTA in order to identify the main causes of events and incidents in the construction of water conveyance tunnels. They used the experience of field experts in the form of linguistic variables in the absence of accurate data as was used in this current study.

4. Conclusion

fire risk assessment of the separation units in selected oil and gas firm in Rivers Sates has been carried out. The findings revealed oil and gas separation units are among most vulnerable operation units to fire accidents in the oil and gas companies. Alsos, there are twelve major fire-related hazards in the separation units and they are grouped into two categories; flammable sources and heat/ignition sources hazards, three, two hazard within these two categories must occur before fire incident will happen in the separation units, Furthermore, the level of risk associated with these hazards in the separation unit fails within "High risk and Extreme risk" levels. Finally, combination of "Leakage of Hydrocarbon due to failure from high pressure flow" a flammable source) and "Failure of temperature controller" a heat/ignition source would generate or trigger the most devastating fire incident in the separator unit. Thus, it is recommended that the management of the selected oil and gas companies should pay a closer attention to the fire-safety of the separation units as it is one of the most vulnerable unit to fire incident in the oil and gas companies

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