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Assessment of Factors Influencing Process Safety Risk Accumulation in Petroleum Operations in Nigeria

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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

A cross-sectional exploratory assessment of the factors that influence process safety cumulative risk for accident prevention in petroleum operations in Niger-Delta Nigeria was investigated. For the study, a purposive cum random sampling technique was deployed among selected petroleum companies operating in Niger-Delta, Nigeria. A population of 261 of asset integrity engineers/operators, process safety experts, production safety professionals in the petroleum industry in the Niger Delta were sampled using survey questionnaires. Descriptive and inferential statistics (analysis of variance) were used for data analysis. Overall, the study established that process safety cumulative risk assessment has a significant influence in major accident prevention in petroleum operations in Niger-Delta, Nigeria. The study identified seven influencing factors that need to be considered by petroleum industries in Niger-Delta Nigeria, in assessing process safety cumulative risk: (a) preventive and corrective maintenance deviations (agreed by 100% of the respondents), (b) temporary changes (agreed by 98% of the respondents), (c) inhibits/overrides (agreed by 96% of the respondents. Also (d) 97% accounted for downgraded integrity items and (e)

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100% accounted for permit to work as influencing factors. The study further showed that (f) simultaneous operations (averred by 99% of the respondents) and (g) open actions from safety review /audits (averred by 92% of the respondents) were the other influencing factors. Including these influencing factors in process safety cumulative risk assessment by the petroleum industries in the study area, will enable better operational decision making in reducing the risk of major accidents.

Keywords: Petroleum operations; cumulative risk; major accident prevention; process safety; Niger-Delta.

1. INTRODUCTION

In the petroleum industries globally, major process safety accidents continue to occur [1]. Even though the occurrence of these major incidents are not frequent, the consequences when they occur are high and these include reputation damage, environmental degradation, multiple fatalities and total loss of assets [2,3] and potential loss of license to operate. The characteristics of these major accidents are not simple to establish and are usually attributable to many factors [3]. According to [4], a combination of many factors ranging from technology failures to human failures, management system failures and even natural phenomena is usually implicated as the causes of the major accidents. Many companies have focused their efforts in preventing these accidents by improving technology and human factors [5]. But in spite of all these major accident prevention initiatives, major accidents continue to occur.

Several major process safety accidents have occurred in the petroleum industry [6] and investigations are usually carried out and recommendations made. In some cases, it was established that the organization were confronted with many issues during the operational phase of the assets, for example symptoms of deteriorating safety critical barriers but the symptoms were ignored or normalized. [7] highlighted that impaired barriers or barrier not operating as intended, are “warning signals” and opined that failure to recognize these warning signals and the cumulative risk impact were contributory factors in many major accidents in the industry. In most of these major accidents, there was dangerous accumulation of process safety risks arising from these warning signals but plant operators were not aware of the cumulative risk impact of these anomalies [8,9]. According to [9], the organizations are usually aware of most of these anomalies in the plant but the cumulative risk of the gaps are not assessed and appropriate mitigations put in place. Often the information is not visible to the people who have the responsibility to intervene. A study by [10] revealed that industry experts have focused on curbing these major process safety events to an appreciable extent, from cumulative risk management point of view. However, there are still many gaps in managing cumulative risk in oil and gas facilities [11]. Granted that many studies have been carried out in process safety management for major accident prevention [12], however the studies that consider the factors that influence process safety cumulative risk in the oil and gas operations are still scant [13]. The aim of this study was to explore factors that influence process safety cumulative risk for prevention of major accidents in the Niger Delta region. Cumulative risk is the combined effect of several risks impacting the safety of the installation / site, focused on the Major Accident Hazards as described in the HSE Case [14].

2. LITERATURE REVIEW

Several major process safety accidents have happened in the oil and gas industry [6] and these major accidents are usually investigated and recommendations made. It was pointed out by [9] that most major accident investigation reports often show that the major hazard organization were confronted with integrity issues during the operational phase of the assets, for example symptoms of deteriorating safety critical barriers but the symptoms were ignored or they were not treated appropriately. [7] highlighted that impaired safeguard and/or having safety critical systems in bypass mode or not operating as intended, are “warning signals” and opined that failure to recognize these warning signals and risk accumulation from them were contributory factors in many major accidents in the industry. This was the case in the Bhopal disaster of 1984 [15], Piper Alpha incident of 1988 [7], Buncefield accident of 2005 [16], BP Texas accident incident of 2005 [17]. [18] stated that about one-third of all CSB events and OSHA's PSM covered incidents involve concerns linked to defects in maintenance, insufficient inspection, poor preventive maintenance, and inadequate mechanical integrity program and the risk arising from these impairments accumulated to result into the major incidents. [11] observed that there are many factors on safety critical barriers that contribute to the accumulation of risks in a facility and these include maintenance backlog, inhibits / bypasses, deferrals, management of change (MOC) program and permit to work practices. In most of the major accidents, process safety risks accumulated due to the degradation of the safety critical barriers and operators were blind-sided to the cumulative risk impact of these deviations. [19,8] recognized that deviations in a facility may have been managed individually but the cumulative risk of many deviations acting together may not have been duly managed, resulting into major accidents.

Evidence from the literatures reviewed showed that factors that influence process safety risk accumulation on major accident risk is not yet fully established, to help in operational risk management in the petroleum sector. Process safety management is covered by suitable laws [12], however the impact of process safety cumulative risk accumulation in the petroleum industry has been the subject of very little research [13].

3. MATERIALS AND METHODS

3.1 Study Area

Niger Delta region in Nigeria is the study area for this work. The petroleum facilities operating within the delineated area are the foci of the researcher. The area situates on latitudes 4°N and 6°N and longitude 5°E and 8°E [20]. Due to the climatic and other environmental characteristics of Niger Delta, in addition to the presence of crude oil, the area is playing host to over 18 multinational oil and gas companies and many national oil and gas companies [21].

3.2 Research Design

A cross-sectional research design was utilized for this study, the key reason for using this research method is that cross-sectional research findings are representative and can be generalized [20]. The study data was obtained from both primary sources (focused group of process safety professionals and survey questionnaire) and secondary sources, to ensure the robustness of information required to achieve the aim and objectives of the study. The data was analysed using qualitative and quantitative techniques such as content analysis, descriptive and inferential statistics (one way analysis of variance). Cronbach’s alpha reliability analysis was used to check the reliability of the survey questionnaire.

3.3 Study Population

Asset integrity engineers/operators, process safety experts, production safety professionals in the petroleum industry in the Niger Delta region of Nigeria formed the population sample for this study. This sample was extracted from both the international and national oil companies domiciled in the study area. In all, 261 participants were used as the sample size of the population. The sample size was determined from Cochrain equation [22] and to account for inefficiencies, a 10% margin was included [22], [23]. The respondents in this study cut across the upstream, midstream and downstream sectors of the petroleum industry in Nigeria.

3.4 Sample and Sampling Technique

This study utilized purposive cum random sampling technique, with 261 asset integrity engineers /operators, process safety experts, production safety professionals in petroleum industry in Niger Delta region used as the target population. 100% of this population was sampled. Two hundred and sixty-one (261) instruments were distributed and two hundred and sixteen (216) were returned and used by the researcher, representing a return rate of 83%.

3.5 Data Collection

Primary and secondary data were utilized for the study. The primary data was collected through a survey questionnaire. Data was collected from a focused group of process safety professionals in Nigeria with minimum of 15 years’ process safety experience in oil and gas operations. Others include a cross-section of asset integrity engineers /operators, process safety experts, production safety professionals in oil and gas industry in Niger Delta region. The focus group comprised of 15 participants, selected by the researcher from oil and gas operators in the Niger-Delta and with a very good knowledge of process safety and risk assessments. A focused group was chosen because it enabled gathering of rich qualitative data [24]. The survey questionnaire was developed from the result of the focused group. The secondary data was collected from process safety journal articles and used to compare with responses from the questionnaire.

A modified 5-point Likert-scale questionnaires was used for the study, to measure the perceptions of the study's participants. Test-retest method was used to check the reliability of the questionnaire. SPSS version 27 was used to check the internal reliability of the questionnaire data, to obtain an acceptable Cronbach's alpha value of 0.78. Reliability analysis is vital to ascertain the consistency of the response scores in the questionnaires [22,23].

The random sampling technique was deployed in this study.

3.6 Data Analysis

Descriptive statistics (mean) was used in data analysis and evaluation of the influence of process safety cumulative risk in major accident prevention in petroleum operations, based on the mean responses. A Likert Mean of ≥3.5 indicated that the statement was accepted among the respondents while a Likert Mean < 3.5 indicated that the statement was rejected by the respondents. To test the hypotheses that "process safety cumulative risk assessment has no significant influence in major accident prevention in petroleum operations in the study area", the one-way analysis of variance was used to compare the mean scores of the participant's responses across the different locations. SPSS version 27 was used for data analysis.

4. RESULTS

The results from this study are presented in the Tables and Figures. Figs. 1, 2, 3, 4 and 5 show the demographic characteristics of the respondents. Table 1 shows the descriptive statistics on influence of process safety cumulative risk assessment on major accident prevention in petroleum operations while Table 2 shows the regression analysis of variance (ANOVA) summary for process safety cumulative risk assessment and accident prevention in petroleum operations in the study area. Table 3 shows the scores and analysis of variance on influence of process safety cumulative risk assessment by locations

4.1 Demography

As shown in Table 1, 216 respondents took part in the survey. On educational qualification, 18% of the respondents have Higher National Diploma, 41% of the respondents have Bachelor's Degree, 28% have Master's Degree and 13% have Doctorate Degree. 33% of the respondents have between 1 to 5 years oil and gas experience, 31% of the respondents have between 6 to 10 years oil and gas experience, 20% of the respondents have above 15 years oil and gas experience and 16% of the respondents have between 11 and 15 years oil and gas experience. 56% of the respondents work in Rivers and Delta States, the two states that have the bulk of oil and gas operations in the Niger Delta region. Table 2 also shows the distribution of the job categories of the participants. The highest proportion were production/asset integrity engineer (31%) followed by production safety professional (28%), process safety engineer (20%), process safety consultant (11%), Academia (6%) and other categories (4%).

4.2 Influence of Process Safety Cumulative Risk in Major Accident Prevention in Petroleum Operations in Niger-Delta

Table 1 shows the descriptive statistics of the perceptions of the respondents on the influence of process safety cumulative risk in major accident prevention in Niger Delta. Overall, respondents agreed to the constructs raised from Survey Questions Q1 to Q12 with a weighted mean that ranged between 3.6 to 4.9. On construct Q1, 100% agreed that major accidents can occur in oil and gas industry when adequate consideration is not given to risks arising from many "holes" (barrier impairments) in the plant, lining up together dangerously. On construct Q2, 99.5% agreed that during Operational Risk Assessment (ORA), if adequate consideration is not given to risks arising from other safety critical impairments in the facility, major accident risk may increase. Again, 99.5% of the responds averred that inadequate consideration of the risks arising from preventive and corrective maintenance impairments alongside other safety critical impairments in the facility may create latent conditions that contribute to the risk of major accidents (Q3). 98.1% of the respondents agreed that every temporary change deviation in a facility including the interactions that is not properly risk assessed may increase the risk of major accident in a facility (Q4) even though 1.85% of the respondents were undecided/aloof about the construct. Majority of the respondents (95.83%) agreed that inadequate risk assessment of a barrier which is overridden or inhibited alongside other impairments in the facility before suitable risk mitigation measures are established may increase major accident risk (Q5). 96.83% of the respondents agreed to the construct Q6 that if downgraded integrity items in a facility are not considered in the overall risk profile of a facility, the risk of major accident may increase. Also ascertained in the study is that most of the respondents agreed (100%) that permit to work management without adequate consideration of risks arising from other safety critical impairments will increase major accident risk (Q7).

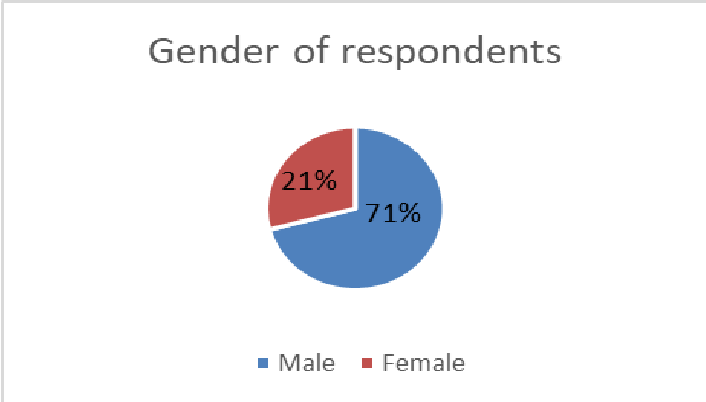

Fig. 1. Distribution of respondents by gender

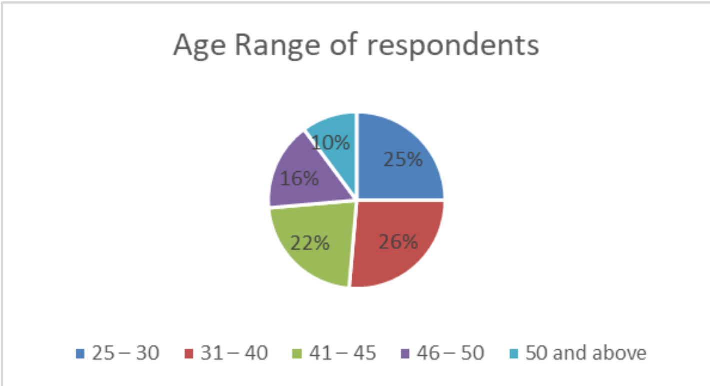

Fig. 2. Distribution of respondents by age

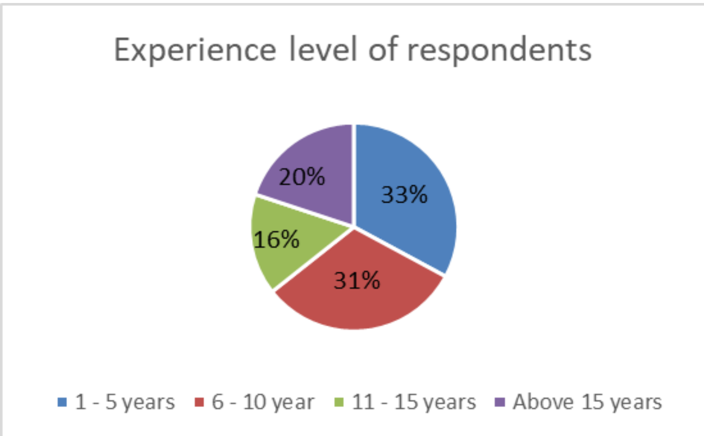

Fig. 3. Distribution of respondents by experience

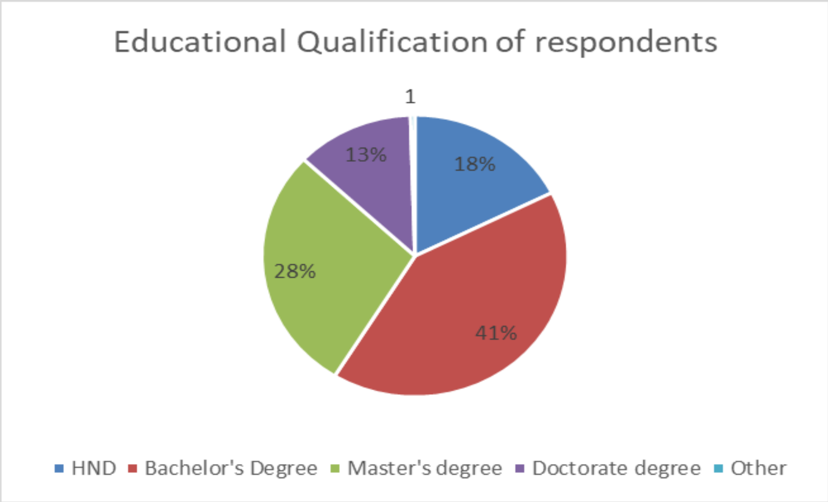

Fig. 4. Distribution of respondents by educational qualification

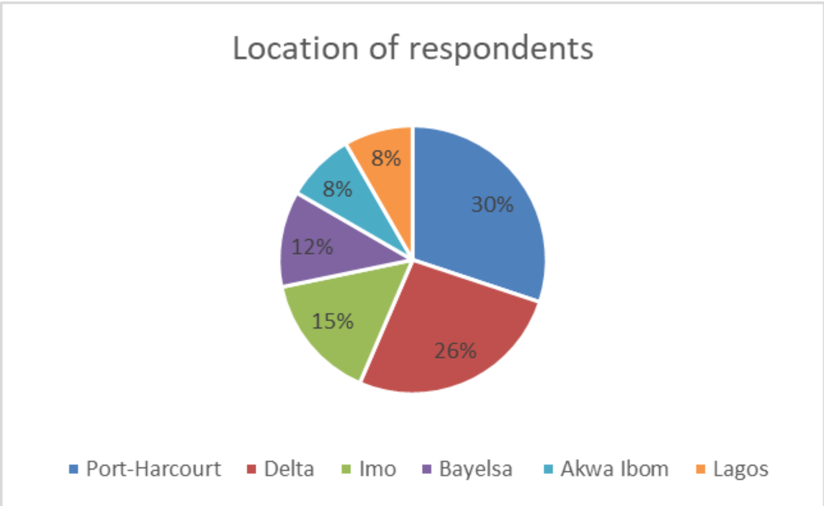

Fig. 5. Distribution of respondents by location

Furthermore, 98.5% of the respondents agreed that inadequate overview of simultaneous operations (SIMOPS) risks against safety critical barrier health status increases the risk of major accidents (Q8). On construct Q9, 40.28% of the respondents disagreed that all backlog (deferral) of planned assurance activities if not properly risk assessed along-side other impairments in the facility may increase major accident risk, even though 59.26% were undecided about the construct. 93.5% of the respondents agreed on construct Q10 that influencing factors such as weather conditions, human factors, etc. if not properly considered may increase the risk of major accidents in a facility. The construct that open actions from assurance audits and safety studies if not properly considered may increase the risk level in a facility (Q10) was agreed by 92.1% of the respondents. Finally, 98.1% of the total respondents agreed that having a means of visualizing the risks arising from multiple safety critical impairments in a facility enables better operational decision taking in reducing major accident risk (Q11).

4.3 Analysis of Variance on Influence of Process Safety Cumulative Risk in Major Accident Prevention in Petroleum Operations in Niger-Delta

Table 2 shows the regression ANOVA summary for process safety cumulative risk assessment and accident prevention in oil and gas operations in the study area. The model is significant at $p<0.05$ ($F=11.7$). This implies that significance is reached and the null hypothesis stating that

Table 1. Influence of process safety cumulative risk assessment on major accident prevention in petroleum operations

S/ No	Item	SA n (%)	A n (%)	N n (%)	D n (%)	SD n (%)	Likert Mean
1.	Major accidents can occur in oil and gas industry when adequate consideration is not given to risks arising from many "holes" (barrier impairments) in the plant, lining up together dangerously	201(93.06)	15(6.94)	0(0.00)	0(0.00)	0(0.00)	4.9
2.	During Operational Risk Assessment (ORA), if adequate consideration is not given to risks arising from other safety critical impairments in the facility, major accident risk may increase	191(88.43)	24(11.11)	0(0.00)	1(0.46)	0(0.00)	4.9
3.	Inadequate consideration of the risks arising from preventive and corrective maintenance deviations / impairments alongside other safety critical impairments in the facility may create latent conditions that contribute to the risk of major accidents	189(87.50)	24(11.11)	2(0.93)	1(0.46)	0(0.00)	4.9
4.	Every temporary change deviation in a facility including the interactions that is not properly risk assessed may increase the risk of major accident in a facility	182(84.26)	30(13.89)	4(1.85)	0(0.00)	0(0.00)	4.8
5.	Inadequate risk assessment of a barrier which is overridden or inhibited alongside other impairments in the facility before suitable risk mitigation measures are established may increase major accident risk	181(83.80)	33(15.28)	2(0.93)	0(0.00)	0(0.00)	4.8
6.	If downgraded integrity items/equipment in a facility is not considered in the overall risk profile of a facility, the risk of major accident may increase	65(30.09)	142(65.74)	8(3.70)	1(0.46)	0(0.00)	4.3
7.	Permit to work management without adequate consideration of risks arising from other safety critical impairments increases major accident risk	85(39.35)	131(60.65)	0(0.00)	0(0.00)	0(0.00)	4.4
8	Inadequate overview of simultaneous operations (SIMOPS) risks against safety critical barrier health status increase the risk of major accidents	79(36.57)	133(61.57)	4(1.85)	0(0.00)	0(0.00)	4.3
9	All backlog (deferral) of planned assurance activities if not properly risk assessed along-side other impairments in the facility may increase major accident risk	46(21.30)	41(18.98)	128(59.26)	1(0.46)	0(0.00)	3.6
10	Open actions from assurance audits and safety studies if not properly considered may increase the risk level in a facility	48(22.22)	151(69.91)	14(6.48)	3(1.39)	0(0.00)	4.1
11	Having a means of visualizing the risks arising from multiple safety critical impairments in a facility enables better operational decision taking in reducing major accident risk	183(84.72)	29(13.43)	3(1.39)	1(0.46)	0(0.00)	4.8

*SA: Strongly agreed, A: Agreed, N: Neutral, D: Disagreed, SD: Strongly disagreed, *Statement is accepted (criterion mean of responses ≥3.5)*

Table 2. The regression ANOVA summary for process safety cumulative risk assessment and accident prevention in oil and gas operations in the study area

ANOVA[a]						
Model		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
1	Regression	.417	1	.417	11.664	.001[b]
	Residual	9.256	259	.036		
	Total	9.673	260			

a. Dependent Variable: Cumulative_risks
b. Predictors: (Constant), Accident_Prevention

Table 3. Mean scores and analysis of variance on influence of process safety cumulative risk assessment by locations

Location	Mean	SD	ANOVA (p-value)
Akwa Ibom	4.58	0.51	0.898**
Bayelsa	4.60	0.46	
Delta	4.59	0.46	
Imo	4.73	0.21	
Lagos	4.06	0.68	
Port-Harcourt	4.49	0.58	

SD: Standard deviation of Mean; ANOVA: Analysis of Variance
***Difference between locations is not statistically significant*

"process safety cumulative risk assessment has no significant influence in major accident prevention in oil and gas operations in the study area" is rejected and the alternate accepted. Thus, process safety cumulative risk assessment has a significant influence in major accident prevention in petroleum operations in the study area.

Table 3 shows the one-way analysis of variance, used to compare the mean scores of the participant's responses across the different locations. The Analysis of Variance showed no significant difference in the mean scores of process safety cumulative risk assessment in the different locations ($p = 0.898$). Therefore, the null hypothesis "Influence of process safety cumulative risk in major accident prevention is not significantly different across the study area" is not rejected.

5. DISCUSSION

The statistics from Figs. 1, 2, 3, 4 and 5 suggest that the study's participants that took part in the survey, were seasoned professionals in the oil and gas industry. The survey also indicated the participants' level of education is high as shown in Fig. 4 and that there was adequate distribution of the research instruments among the Niger Delta States participants' geographical location as shown in Fig. 5. These demographic data also suggested that based on the respondents' level of education and years of experience as shown in Fig. 3, they have reasonable knowledge about process safety cumulative risk and its influence in major accident prevention in oil and gas operations in Niger Delta. Indeed, the participants' level of industry experience enhances the reliability of this study, as it indicates that most participants have vast experience in the oil and gas industry. This aligns with the recommendation by [25] on the use of experienced professionals to enhance the reliability of study findings.

From Table 1, one general deduction from this study is that major accidents can occur in oil and gas industry when adequate consideration is not given to risks arising from many "holes" (barrier impairments) in the plant, lining up together dangerously. This was agreed by 100% of the respondents. 99.5% of the respondents also agreed that during Operational Risk Assessment (ORA), if adequate consideration is not given to risks arising from other safety critical impairments in the facility, major accident risk may increase. These agreements align with [26] that risk of major accident can increase due to adverse effects on the barriers, or other abnormal operational situations in a processing plant and recommended that operational procedures for risk management need to be dynamic to take account of all these deviations. Also collaborated by [27], the risk of major accident is a facility starts to increase as barriers start to degrade at different rates, pointing out that some of these barrier failures can increase risk dramatically, especially where there are barrier dependencies. [9] also buttressed these positions by stating that deviations on safety critical barriers create holes and the risk they portend may have been managed individually but the cumulative risk of the deviations acting together may not have been duly managed. [28] while referring to Deepwater Horizon incident of 2010, observed that all barriers have holes that may line up and allow a hazard to penetrate the system and these barriers degrade over time, and the system may gradually and unnoticeably drift towards a state of high risk if the size of the holes continues to increase. [29] provides examples of how deviations can contribute to hydrocarbon leaks.

There was a full agreement that inadequate consideration of the risks arising from preventive and corrective maintenance hardware barrier impairments alongside other safety critical impairments in the facility may create latent conditions that contribute to the risk of major accidents (99.5%). [30] aligns with these views by stating that as assets undergo integrity degradation during their operational life (referring to the hardware barriers), process safety risk (major accident risk) fluctuates with changing system conditions, on-going operations and maintenance activities and opined that the key challenge is on how to manage the accumulation of the risks during the operate phase of an asset. This also buttresses the view of [7] that impaired or degraded safety critical barriers are "warning signals" and the failure to recognize these warning signals and the cumulative risk impact were contributory factors in many major accidents in the industry. These deviations amount to a degraded mode of operation (degraded operation arises when a barrier performance reduces or a barrier loses its ability to perform its intended function), which according to [31], may increase the risk of major accidents and mitigating measures should therefore be considered.

There is also a full agreement (98.1%) that every deviation in a facility including the interactions that is not properly risk assessed may increase the risk of major accident in a facility. This again aligns with the view of [9] that risk accumulates from inappropriate management of multiple deviations, increasing the risk of major accidents. This is further buttressed by [32], stating that operational risks can arise from deviation arising from critical equipment conditions, non-conformances and planned activities on the facility and recommended that a new approach to manage the cumulative impact of all the risks arising from these deviations is required, to reduce risk exposure. [11] also recognized maintenance backlogs and deferrals as deviations and one of the major accident influencing factors.

As agreed by majority of the respondents (95.83%), inadequate risk assessment of a barrier which is overridden or inhibited alongside other impairments in the facility before suitable risk mitigation measures are established may increase major accident risk. This is fully aligned with the view expressed by [32] that overrides /inhibits are part of operational deviations that increase the risk of major accidents and recommended a model that provide a better illustration of their impact on major accident risk for better decision making. [33] also recognized that overrides, inhibits can defeat the performance of technical barriers and this may increase major accident risk if not properly managed. [11] also recognized that inhibits and overrides are one of the major accident influencing factors and aligns with the view of [26] that major risk assessment should consider the impact of any deviations or any known inhibits or over-rides that are in place, to allow continued operation.

96.83% of the respondents agreed that if downgraded integrity items in a facility are not considered in the overall risk profile of a facility, the risk of major accident may increase. According to [34], “a downgraded situation can be defined as an abnormal situation, where a facility is operating outside its context of definition, resulting in an increase in operation-related risk”. At the time of Piper-Alpha incident of 1988, the firewater pumps which were designed for 2 x 100% duty were downgraded to 1 x 100% duty due to maintenance and the only duty fire pump could not be started due to diving operations in the facility at the time of the incident [35]. Considering downgraded integrity items in overall risk profile in a facility aligns with the view of [34] that tools are required for designing early detection systems for decision support.

Also ascertained in the study is that most of the respondents agreed (100%) that permit to work management without adequate consideration of risks arising from other safety critical impairments will increase major accident risk. [36] supports this position by stating that instructions to perform a task and the necessary risk control measures are usually covered in a permit to work and non-consideration of other risks in the facility can increase the risk exposure in the facility. [11] also identified permit-to work practice as one of the major accident influencing factors. However, [14] stated that permit to work system is not designed to manage cumulative risk especially when there are multiple deviations in a facility.

Furthermore, 98.5% of the respondents agreed that inadequate overview of simultaneous operations (SIMOPS) risks against safety critical barrier health status increases the risk of major accidents, thereby aligning with the view of [37] that inappropriate attention to scheduling for simultaneous work activities can pre-dispose an asset to a major accident. [18] also collaborated this view by stating that some of the major accidents in the process industry involved simultaneous operations. 40.28% of the respondents disagreed that all backlog (deferral) of planned assurance activities if not properly risk assessed along-side other impairments in the facility may increase major accident risk. This is against the view expressed by [26] that deferred assurance activities should be considered in managing cumulative risk, to reduce the risk of major accidents in the oil and gas industry. Open actions from safety studies if not properly considered may increase the risk level in a facility. 92.1% of the respondents agreed to the construct. Non-closure of a previous safety studies action was one of the pre-conditions for the BP Texas refinery incident [17] and Bhopal Iso-cyanade incident [38]. 93.5% of the respondents agreed that influencing factors such as weather conditions, human factors, etc. if not properly considered may increase the risk of major accidents in a facility. This aligns with the opinion of [25] that climate (weather) is one of the causes of major accidents and the author developed a process safety management system that includes climatic changes as one of the risk factors. Human factors have also been identified by [39] as a leading cause of major industrial accidents.

Finally, 98.1% of the total respondents agreed that having a means of visualizing the risks arising from multiple safety critical impairments in a facility enables better operational decision taking in reducing major accident risk. This agrees with the opinion of [19] that a good risk visual tool will provide plant operators with a process safety risk visibility so that normalizing deviations can be minimized and assist them in focusing facility mechanical integrity program on the barriers that contribute most to risk reduction. [40] stated that visualization of risk factors is one of the best major accident prevention measures.

From the regression ANOVA summary for process safety cumulative risk assessment and major accident prevention in oil and gas operations in the study area in Table 2, it is established that process safety cumulative risk assessment has a significant influence in major accident prevention in petroleum operations in Niger-Delta Nigeria. This was collaborated in a study by [11] suggesting that a risk model is required to focus on real time basis, on the cumulative risk arising from deviations in safety critical barriers while at the same time considering other influencing factors such as maintenance backlogs, inhibits and overrides, overdue preventive maintenance works, conflicting work orders, etc. [9] also pointed out that accident investigation reports of major accidents indicate that most of these accidents were caused by many gaps in the system that were known to the organization but the cumulative risk impacts were not assessed and understood, making the people with the responsibility to intervene unaware of the risks. United Kingdom Oil and Gas Operators also recognized this view by issuing guidelines [14] on how to manage process safety cumulative risk in the United Kingdom.

From Table 3 - the One Way Analysis of Variance (ANOVA) with a p-value of 0.898, it was a clear indication that the perceptions of respondents on the influence of process safety cumulative risk on major accident prevention in Niger-Delta are relatively same across the study area, as the ANOVA result showed that there is no significant variation in the perceptions across the locations in the study area. This conclusion aligns with the view of [41] that most issues and challenges with managing major accident risk are common across oil and gas facilities and locations.

Overall, the study established that process safety cumulative risk assessment has a significant influence in major accident prevention in petroleum operations in Niger-Delta Nigeria and concluded that having a means of visualizing the risks arising from multiple safety critical impairments in a petroleum facility in Niger-Delta will enable better operational decision taking in reducing major accident risk. The study identified 7 influencing factors that need to be considered by petroleum industries Niger-Delta Nigeria, in assessing process safety cumulative risk: preventive and corrective maintenance deviations, temporary changes, inhibits/ overrides, downgraded integrity items, permit to work, simultaneous operations, open actions from safety review /audits.

6. CONCLUSION

The aim of the study was to assess the factors that influence process safety cumulative risk in major accident prevention in petroleum operations in the Niger Delta, Nigeria. A purposive cum random sampling technique was used in this study among petroleum companies operating in Niger-Delta, Nigeria. Survey questionnaires were administered to obtain respondents perception on the factors influencing process safety cumulative risk in petroleum operations. Data analyses were carried out to cover descriptive and inferential statistics. Through this exploratory study, seven influencing factors that need to be considered by petroleum industries, in assessing process safety cumulative risk were identified: preventive and corrective maintenance deviations, temporary changes, inhibits/overrides, downgraded integrity items, permit to work, simultaneous operations, open actions from safety review /audits. Including these influencing factors in process safety cumulative risk assessment by the petroleum industries in the study area, will enable better operational decision making in reducing the risk of major accidents.

CONSENT

As per University requirement, a written consent was sought and obtained from respondents and subsequently preserved by the Arthurs.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Bubbico R, Lee S, Moscati D, Paltrinieri N. Dynamic assessment of safety barriers preventing escalation in offshore Oil & Gas. Saf Sci. 2020;121: 319-30.
   DOI 10.1016/j.ssci.2019.09.011.
2. Kongsvik T, Almklov P, Haavik T, Haugen S, Vinnem JE, Schiefloe PM. Decisions and decision support for major accident prevention in the process industries. J Loss Prev Process Ind. 2015;35:85-94.
   DOI 10.1016/j.jlp.2015.03.018.
3. Okoh P, Haugen S. A study of maintenance-related major accident cases in the 21st century. Process Saf Environ Prot. 2014;92(4):346-56. DOI: 10.1016/j.psep.2014.03.001.
4. Bubbico R, Lee S, Moscati D, Paltrinieri N. Dynamic assessment of safety barriers preventing escalation in offshore Oil &Gas. Saf Sci. 2020;121(June):319-30.
   DOI 10.1016/j.ssci.2019.09.011.
5. Meng X, Zhang Y, Yu X, Bai J, Chai Y, Li Y. Regional environmental risk assessment for the Nanjing Chemical Industry Park: an analysis based on information-diffusion theory. Stoch Environ Res Risk Assess. 2014;28(8): 2217-33.
   DOI 10.1007/s00477-014-0886-3.
6. Ismail Z, Kong KK, Othman SZ, Law KH, Khoo SY, Ong ZC et al. Evaluating accidents in the offshore drilling of petroleum: regional picture and reducing impact. Measurement. 2014; 51(1):18-33.
   DOI: 10.1016/j.measurement.2014.01.027.
7. Hirak Dutta executive director oil industry safety Directorate 27; 2013.
8. Pawłowska Z. Using lagging and leading indicators for the evaluation of occupational safety and health performance in industry. Int J Occup Saf Ergon. 2015;21(3):284-90.
   DOI: 10.1080/10803548.2015.1081769
9. Refsdal I, Urdahl O. Technical integrity management in Statoil Soc. Pet. Eng. - 30th Abu Dhabi Int. Pet. Exhib. Conf. ADIPEC. Chall Oppor Next 30 Years. 2014;2:1456-67.
10. Al-shanini A, Ahmad A, Khan F. Accident modelling and analysis in process industries. Journal of Loss Prevention in the Process Industries. 2014;32:319–334.
    Available:https://doi.org/10.1016/j.jlp.2014.09.
11. Behie SW, Halim SZ, Efaw B, O'Connor TM, Quddus N. Guidance to improve the effectiveness of process safety management systems in operating facilities. J Loss Prev Process Ind. 2020;68(June):104257.
    DOI: 10.1016/j.jlp.2020.104257.
12. Lee K, Kwon H, Cho S, Kim J, Moon I. Improvements of safety management system in Korean chemical industry after a large chemical accident. J Loss Prev Process Ind. 2016;42:6-13.
    DOI: 10.1016/j.jlp.2015.08.006.
13. Blacklaw A, Ward A, Cassidy K. The cumulative risk assessment barrier model Soc. Pet. Eng. - Offshore Eur. Oil Gas Conf. Exhib. 2011, OE 2011; 2(September):915-25.
    DOI: 10.2118/146255-MS.
14. OGUK. Cumulative risk guidelines. 2016;1:1-34.
15. Varma R, Varma DR. The Bhopal Disaster of 1984. Bull Sci Technol Soc. 2005;25(1):37-45.
    DOI: 10.1177/0270467604273822.
16. Hailwood M, Gawlowski M, Schalau B, Schönbucher A. Conclusions drawn from the Buncefield and Naples incidents regarding the utilization of consequence models. Chem Eng Technol. 2009; 32(2):207-31.
    DOI: 10.1002/ceat.200800595.
17. Hopkins. Failure to learn: the BP Texas City refinery disaster. CCH, 2008.
18. Baybutt P. Insights into process safety incidents from an analysis of CSB investigations. J Loss Prev Process Ind. 2016;43:537-48.
    DOI: 10.1016/j.jlp.2016.07.002.
19. Jonassen Ø, Sjølie E. Barrier management in operation for the rig industry - A joint industry project. OTCA Offshore Technol Conf. Asia. Vol. 2016(1980). 2016;388-95.
    DOI: 10.4043/26819-MS.
20. Jia JA, Nwaogazie IL, Anyanwu BO. Risk matrix as a tool for risk analysis in underwater operations in the oil and gas industry. JEP. 2022;13(11):856-69.
    DOI: 10.4236/jep.2022.1311054.

21. Uzoma C, Mgbemena O.. Evaluation of some oil companies in the development of Niger Delta region of Nigeria Int. J. Environ. Pollut Res. 2015;3(8): 13-31. [online].
Available: http://www.iosrjournals.org.
22. Singh S, Ajay, Masuku MB. Sampling Techniques & Determining Sample Size in Applied Statistics Research: an Overview. Int. J. Econ. Commer. Manag. 2014;II(11): 1–22.
23. II JEB, Kotrlik JW, Higgins CC. Determining appropriate sample size in survey research. Inf. Technol. Learn. Perform. J. 2001;19(1):43–50 [Online].
Available: https://www.opalco.com/wp-content/uploads/2014/10/Reading-Sample-Size1.pdf.
24. Hoseini E, Hertogh M, Bosch-Rekveldt M. Developing a generic risk maturity model (GRMM) for evaluating risk management in construction projects. J Risk Res. 2021;24(7):889-908.
DOI:10.1080/13669877.2019.1646309.
25. Nwankwo CD. Development of an Integrated Process Safety Management and Climate Change Model for the Oil and Gas Industry; 2020, [Online].
Available:https://pureportal.coventry.ac.uk/files/37907377/Nwankwo_Pure.pdf.
26. "RiskPoynt Cumulative Risk Guidance RiskPoynt Guideline Cumulative Operational Risk Assessment Document and Version Control."
27. Pitblado R, Fisher M, Nelson B, Fløtaker H, Molazemi K, Stokke A. Dynamic barrier management – Managing safety barrier degradation. Inst Chem Eng Symp Ser. 2016;161:1-8.
28. Johansen IL, Rausand M. Barrier management in the offshore oil and gas industry. J Loss Prev Process Ind. 2015;34:49-55.
DOI: 10.1016/j.jlp.2015.01.023.
29. Sarshar S, Haugen S, Skjerve AB. Factors in offshore planning that affect the risk for major accidents. J Loss Prev Process Ind. 2015;33:188-99.
DOI:10.1016/j.jlp.2014.12.005.
30. Ratnayake RMC. Modelling of asset integrity management process: a case study for computing operational integrity preference weights. IJCSYSE. 2012; 1(1):3.
DOI:10.1504/IJCSYSE.2012.044738.
31. SINTEF. Guidance for barrier management in the petroleum industry; 2016.
DOI: 10.13140/RG.2.2.16611.76323.
32. Jones SR. Managing process safety in the age of digital transformation. Chem Eng Trans. 2019;77(June):619-24.
DOI: 10.3303/CET1977104.
33. Note G. Core concepts. 2020;1-22.
34. Camara S et al. Digital twin design requirements in downgraded situations management to cite this version: HAL Id: hal-03262607; 2021.
35. Cullen THL. Piper Alfa. The Public Enquiry Piper Alpha Disaster. 1990.
36. de Almeida G, Vinnem JE. Major accident prevention illustrated by hydrocarbon leak case studies: A comparison between Brazilian and Norwegian offshore functional petroleum safety regulatory approaches. Saf Sci. 2020;121(August): 652-65.
DOI: 10.1016/j.ssci.2019.08.028.
37. Andersen S, Mostue BA. Risk analysis and risk management approaches applied to the petroleum industry and their applicability to IO concepts. Saf Sci. 2012;50(10):2010-9.
DOI:10.1016/j.ssci.2011.07.016.
38. Process safety and environmental protection learning (and unlearning) from failures: 30 years on from Bhopal to Fukushima an analysis through reliability engineering techniques Ashraf Labib, University of Portsmouth, UK. Email: ashraf.labib@port.ac. MIC. 2014;610, no:1-21.
39. Nwankwo CD, Arewa AO, Theophilus SC, Esenowo VN. Analysis of accidents caused by human factors in the oil and gas industry using the HFACS-OGI framework. Int J Occup Saf Ergon. 2022;28(3):1642-54.
DOI 10.1080/10803548.2021.1916238.
40. Sarshar S, Haugen S. Visualizing risk related information for work orders through the planning process of maintenance activities. Saf Sci. 2018;101(September): 144-54.
DOI:10.1016/j.ssci.2017.09.001.

41. Sarshar S, Haugen S, Skjerve AB. Challenges and proposals for managing major accident risk through the planning process. J Loss Prev Process Ind. 2016; 39:93-105.
DOI:10.1016/j.jlp.2015.11.012.

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