

Assessment of Process Safety Management Practices in Petroleum Storage Depots in Northern Nigeria

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Abstract

This study assessed process safety management practices in petroleum storage depots in northern Nigeria. The study adopted cross-sectional research design with cluster sampling technique. The study used the questionnaire as its instrument for data collection. The study population was 1022 and sample size of 300 respondents was administered to the depot staff using the Taro Yamene formular. The findings revealed that the mean scores, questions related to risk mitigation (question 5) and technological advancement (question 7) received slightly higher average ratings (3.54 and 3.47, respectively), indicating a generally favorable perception in these areas. Conversely, questions on regulatory compliance (question 4) and safety culture (question 6) scored marginally lower (3.46 and 3.4), reflecting moderate agreement and potential areas for improvement. The weighted means, which consider the distribution of responses across different levels of agreement, reinforce this pattern by showing that perceptions of risk management and technology adoption are relatively stronger, whereas compliance and safety culture perceptions are weaker, highlighting where organizational focus should be directed for enhancement. The study has recommended that benchmarking against industry standards can help depots create tailored strategies, enhancing safety, compliance, and fostering a resilient operational environment.

Keywords: Depot, Management, Petroleum, Practice, Storage, Safety

Introduction

The petroleum storage sector in Nigeria plays a critical role in the nation's energy supply chain, serving as a vital link between crude oil production and downstream distribution. With the increasing demand for petroleum products driven by economic growth and urbanization, the safety of storage facilities has become an imperative concern [1]. Petroleum storage depots, particularly in the northern regions of Nigeria, are subject to numerous operational and environmental risks that can lead to catastrophic incidents if not properly managed [2]. Therefore, effective process safety management (PSM) practices are essential to mitigate hazards, prevent accidents, and ensure the safety of personnel, assets, and the surrounding communities.

Process Safety Management is a comprehensive approach that integrates technical, organizational, and human factors to control the risks associated with hazardous substances and processes [3]. Globally, numerous industries have adopted PSM frameworks to minimize the frequency and severity of process-related accidents. In the context of petroleum storage

depots, PSM involves rigorous procedures for hazard identification, risk assessment, safety training, emergency preparedness, and continuous improvement. Despite the significance of these practices, there is limited empirical data on the extent of their implementation and effectiveness within the Nigerian petroleum sector, especially in the northern regions where operational challenges are often compounded by infrastructural and regulatory issues [4].

The unique geographical, economic, and socio-political characteristics of Northern Nigeria influence the safety practices adopted by petroleum storage facilities in the area. Factors such as inadequate infrastructure, limited regulatory oversight, and resource constraints can hinder the full implementation of international safety standards [5]. Furthermore, the rapid expansion of storage capacities without commensurate safety measures has heightened the risk of accidents, environmental pollution, and loss of life [6]. An assessment of current safety management practices in this context is therefore crucial to identify gaps, challenges, and opportunities for improvement tailored to the regional specifics.

In Nigeria, the rising demand for petroleum products has increased the need for reliable and safe storage facilities, with regulators promoting local content in their design and operation to conserve foreign exchange and create jobs [7]. The establishment and operation of storage facilities for products such as PMS, AGO, DPK, and others must adhere to guidelines set by the Nigerian Midstream and Downstream Petroleum Regulatory Authority (NMDPRA). These petroleum products are vital to society, derived mainly through fractional distillation of crude oil, and are regulated by agencies like NMDPRA [8]. It is important to integrate Nigerian oil and gas standards with international best practices to assess key safety aspects, including tank sizing, pump selection, pipeline hydraulics, hazard zone classification, and conducting systematic hazard and operability (HAZOP) studies for petroleum depots [9]. Existing literature on process safety management primarily focuses on global best practices and case studies from developed countries, with comparatively sparse data on Nigeria’s petroleum sector. This research aims to bridge this gap by systematically evaluating the safety management practices employed in petroleum storage depots in Northern Nigeria.

Materials and Method

The latitude and longitude of Northern Nigeria are approximately 10.5167° N and 7.4333° E. This region is distinct from the southern part of Nigeria, having its own customs and security structures.

The climate in Northern Nigeria, characterized by high temperatures often exceeding 40°C during the dry season from March to May and lower temperatures in the northern hilly areas, along with relatively low annual rainfall ranging from 500 mm to 1,000 mm, shapes the region’s vegetation, which mainly consists of savanna and semi-arid landscapes. This climate pattern impacts agricultural activities, as the combination of limited rainfall and high temperatures makes farming more challenging.

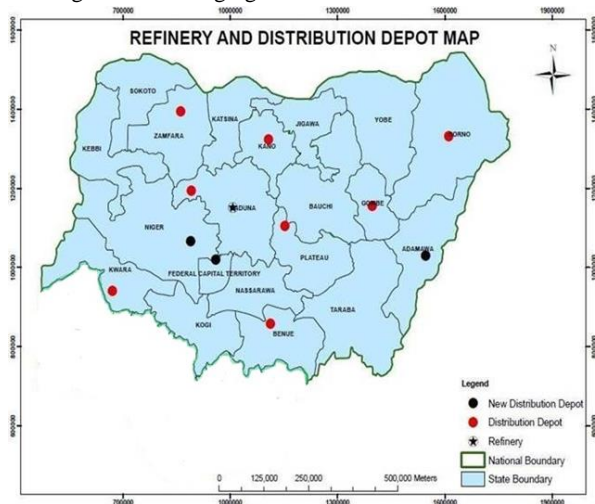


Figure 1: Petroleum Depot Distribution Map of Nigeria

The research design for this study was cross-section approach. Cross-section research design studies a population at a single

point in time to analyze variables and identify patterns or differences. Also, the study adopted cluster sampling technique to provide a comprehensive assessment of process safety management practices in petroleum storage depots in Northern Nigeria. Cluster sampling involves dividing the population into groups, then randomly selecting entire clusters to represent the whole population. The depots form the clusters in Kaduna, Jos, Minna, Kano, Gombe and Yola respectively. Following this, structured questionnaires were developed and distributed to key personnel, including safety managers, engineers, and operational staff within the selected depots, to gather quantitative data on the current safety procedures, training programs, hazard identification methods and safety culture. The questionnaire was divided into two sections of A and B. Section A was the background of respondents and section B was the Process Safety Management Practices in Petroleum Storage Depots in Northern Nigeria.

The study used 4-point Likert scale technique of strongly agreed, agreed, disagree and strongly agreed. Data were analyzed using mean, standard deviation and weighted average to understand the answers with low and high responses in the excel and SPSS analytical environments. Out of population of 1022 staff of selected depots, a total of 300 questionnaires were randomly administered using the Taro Yemane formular stated as (Table 1):

$$n = N/1 + N(e)^2$$

Where:

- n = sample size
- N = number of people in the population
- e = allowable error (%)
- N = 1,022
- e = 0.05
- n = 1,022/1+1,022(0.05)²
- n = 300 questionnaires (Approximately)

Table 1: Population of Depot Staff and Sample of Administered Questionnaires

S/N	Depot	Category	No. of Staff	Total	No. of Samples
1.	Minna	Depot Staff	13	139	50
		Security	25		
		Marketers	95		
		Regulator	6		
2.	Jos	Depot Staff	12	174	50
		Security	37		
		Marketers	120		
		Regulator	5		
3.	Kano	Depot Staff	10	222	50
		Security	28		
		Marketers	180		

		Regulator	4		
4.	Kaduna	Depot Staff	15	245	50
		Security	35		
		Marketers	190		
		Regulator	5		
5.	Gombe	Depot Staff	17	114	50
		Security	23		
		Marketers	70		
		Regulator	4		
6.	Yola	Depot Staff	14	128	50
		Security	30		
		Marketers	80		
		Regulator	4		
Total			1,022	300	

Results and Discussion

The table 2 represents a descriptive statistics analysis of the response rate for a survey. The number of questionnaires administered column indicates the total number of questionnaires distributed to each respondent, which is 300. The number of questionnaires retrieved column indicates the total number of completed questionnaires returned by each respondent, which is also 100. The number not retrieved column is 0, indicating that all questionnaires were successfully completed and returned. This high response rate is due to the effective distribution and collection of questionnaires.

Upon analyzing the data, it is clear that the response rate is 100% for each respondent (Minna, Jos, Kano, Kaduna, Gombe). This suggests that the survey data collection was highly effective, with no missing or incomplete questionnaires. The valid percentage column indicates the percentage of valid responses, which is 16.7% for each respondent. Total row confirms that the overall response rate is indeed 100%, indicating a highly successful survey with no missing data.

Table 2: Response Rate

Respondents	Number of Questionnaires Administered	Number of Questionnaires Retrieved	Number Not Retrieved	Valid Percentage
Minna	50	50	0	16.7
Jos	50	50	0	16.7
Yola	50	50	0	16.7
Kaduna	50	50	0	16.7

Gombe	50	50	0	16.7
Kano	50	50	0	16.7
Total	300	300	0	100

Table 3 presents a descriptive statistical analysis of the demographic characteristics of 300 respondents, categorized by sex, age, and highest level of education. The data indicates a gender distribution with 66.75% males and 33.25% females, revealing a higher representation of males within the sample. Age-wise, the respondents are fairly evenly distributed across the age groups, with the largest proportion (30.5%) falling within the 31-40 years category, followed closely by the 26-30 years group at 29%. The youngest group, below 25 years, comprises 17.75%, while those aged 41 and above represent 23%, suggesting a relatively balanced age distribution that spans early adulthood to middle age.

Regarding educational attainment, respondents' highest levels of education vary, with the most common qualification being the College of Education at 20.5%, followed by the 'Others' category at 17.75%. Participants with Polytechnic education account for 18.25%, while those with Secondary Education and University degrees make up 14.25% and 16.75%, respectively. The primary education group is the smallest at 12.5%. Overall, the demographic profile suggests a diverse sample in terms of age and education, but with a notable male dominance. These distributions provide essential context for analyzing responses and understanding the representativeness of the sample in relation to the population being studied.

Table 3: Background Information of Respondents

S/N	Characteristics	Respondent's Category	Frequency	Percentage
1.	Sex	Male	200	66.75
		Female	100	33.25
		Total	300	100.0
2.	Age	Below 25 Years	53	17.75
		26-30 years	87	29
		31-40 years	91	30.5
		41 years and above	69	23
		Total	300	100.0
3.	Highest Level of Education:	Primary Education	37	12.5
		Secondary Education	42	14.25
		College of Education	61	20.5
		Polytechnic	54	18.25

	University	50	16.75
	Others	56	17.75
	Total	300	100.0

Table 4 represents a quantitative analysis of responses to a series of questions related to organizational performance. The responses are measured on a scale, with 'SA' (Scale Anchor) denoting the highest agreement and 'D' (Dissatisfactory) denoting the lowest agreement. The 'Total' column represents the sum of the individual responses for each question, and the 'Mean' column calculates the average response. The 'SD' (Standard Deviation) column measures the variability of the responses.

A comparison of the responses reveals some interesting patterns. Questions 4 and 6 have been classified as 'Low Response,' whereas questions 5 and 7 have been categorized as 'High Response.' This discrepancy indicates that the depot is doing relatively well in terms of risk assessment and

management (question 5) and embracing technological advancements and automation solutions (question 7). Conversely, the depots may be struggling with regulatory compliance (question 4) and process safety culture (question 6). The 'Mean' column also suggests that the average responses for all questions are close to 3.47, indicating a moderate level of agreement among the respondents.

Based on the analysis, it appears that the depots benefit from improving its regulatory compliance and process safety culture. The 'Low Response' classification for questions 4 and 6 suggests that there is room for improvement in these areas. On the other hand, the 'High Response' classification for questions 5 and 7 indicates that the organization is doing well in terms of risk assessment and management and embracing technological advancements. The 'Decision' column, which categorizes the responses as 'Low Response' or 'High Response,' provides a quick summary of the analysis, allowing decision-makers to focus on the areas that require improvement.

Table 4: Process Safety Management Practices in Petroleum Storage Depots

S/N	Questions	SA	A	SD	D	Total	Mean	SD	Decision
4.	To what extent do you agree that your organization adheres to regulatory compliance?	92	112	50	46	300	3.46	2.75	Low Response
5.	To what extent do you agree that your organization effectively mitigates risk assessment and management?	52	67	71	110	300	3.54	2.1	High Response
6.	To what extent do you agree that your organization has established a strong process safety culture?	79	95	87	39	300	3.4	2.72	Low Response
7.	To what extent do you agree that your organization embraces technological advancements and automation solutions?	87	101	58	54	300	3.47	2.67	High Response

1= Strongly Agree (SA), 2 = Agree (A), 3 = Disagree (D), 4 = Strongly Disagree (SD) and Weighted Average = 3.47

The analysis suggests that the depots can significantly enhance their operational performance by strengthening regulatory compliance and fostering a robust process safety culture. Regulatory compliance ensures that depots adhere to legal standards and industry regulations, thereby reducing the risk of penalties, legal actions, and operational disruptions [10]. Improving compliance not only minimizes legal liabilities but also promotes a safer working environment, which is crucial in high-risk industries such as logistics and

warehousing. Moreover, a strong process safety culture involves the collective commitment of employees and management to prioritize safety in daily operations, which has been shown to decrease accidents and incidents [11]. By aligning safety practices with regulatory requirements, depots can create a proactive safety environment that mitigates risks before they materialize.

Furthermore, integrating a comprehensive safety culture can lead to long-term benefits such as enhanced reputation,

increased operational efficiency, and reduced costs associated with accidents and non-compliance [12]. Organizations that invest in safety culture initiatives often see improved employee morale and engagement, which contribute to better safety practices and knowledge sharing among staff. In the context of depots, where the handling of hazardous materials and heavy machinery is common, maintaining high standards of safety and compliance is crucial for sustainability and resilience [13]. Therefore, the analysis underscores that focusing on regulatory compliance and cultivating a safety-oriented culture is essential for depots to achieve safer, more efficient, and legally compliant operations.

Conclusion

This study Assessed the process safety management practices in petroleum storage depots in northern Nigeria. The findings emphasize the importance of strategic focus on regulatory compliance and safety culture as areas for improvement. Strengthening these aspects can lead to a more comprehensive safety framework that complements the depot's existing strengths in risk management and technological integration. By prioritizing these identified weaknesses, decision-makers can implement targeted policies, training, and safety initiatives that foster a proactive safety environment. Ultimately, advancing in these areas will not only mitigate risks but also reinforce the depot's commitment to operational excellence and regulatory adherence, contributing to its long-term resilience and success. It is recommended stakeholders to investigate the impact of leadership commitment, training programs, and communication strategies on identified low responses order to offer valuable guidance for implementing sustainable improvements. Furthermore, expanding the scope to include benchmarking against industry standards or best practices could help depots develop tailored strategies to elevate their safety and compliance performance, ultimately fostering a more resilient and safety-oriented operational environment.

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