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ASSESSING THE ROLE OF HAZARD IDENTIFICATION IN ENSURING PIPELINE INTEGRITY

Wisdom Japhet OKPAKU
Centre for Logistics and Transport Studies
University of Port Harcourt, Nigeria
okpakuwisdom@gmail.com

Ephraim Ikechukwu ELENWO
Centre for Logistics and Transport Studies
University of Port Harcourt, Nigeria

ABSTRACT

The contribution of hazard identification to pipeline integrity along the Port Harcourt–Osisioma right-of-way in Nigeria's Rivers and Abia States was assessed in this study. The assessment included risks associated with corrosion, vandalism, illegal tapping, encroachment, flooding, operational failures, and third-party participation. The design employed was a survey. Using purposive and stratified sampling, 150 questionnaires were distributed to pipeline operators, maintenance personnel, regulatory bodies, and local government officials. 148 valid responses, or 98.7% of the disseminated questionnaires, were analyzed using frequencies, percentages, mean scores, standard deviations, and basic linear regression at the .05 significant level. Results revealed how stakeholders perceived the identification of hazards. 66.89% of respondents said pipeline operators regularly find risks early, 58.79% said hazard identification is complete, 63.52% said detection mechanisms are successful, and 66.22% said community monitoring enhances detection. However, neutral replies revealed inconsistent implementation, insufficient coverage of technical, environmental, and human-induced risks, and shortcomings in integrating detection and reporting systems, especially when it came to the thoroughness of hazard identification. The study comes to the conclusion that while hazard identification improves pipeline integrity, it still has to be strengthened. Risk-based evaluations, in-line inspection and corrosion monitoring, enhanced right-of-way surveillance, timely maintenance of problems found, more stringent regulatory enforcement, and organized community reporting procedures are all recommended by the study.

Keywords: Hazard Identification, Pipeline Integrity, Risk-Based Management, Right-Of-Way Surveillance, Port Harcourt, Osisioma Pipeline.

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INTRODUCTION

Reliable pipeline operations assist energy availability, industry production, government income, and overall economic development in petroleum-dependent economies like Nigeria. However, the advantages of pipeline transportation rely on operators' capacity to keep pipelines intact for the duration of the asset's useful life. According to Khan, Yarveisy, and Abbassi (2021) and Biezma et al. (2020), pipeline failure can lead to product losses, fires, explosions, environmental contamination, disruption of the energy supply, property damage, and threats to human lives and livelihoods.

The capacity of a pipeline system to function securely, dependably, and effectively without leakage, rupture, or loss of containment is referred to as pipeline integrity. It takes more than just regular inspections and adherence to technical requirements to maintain integrity. It entails the methodical detection and control of circumstances that could erode pipeline components or raise the risk of failure. As a result, risk-based systems that integrate inspection data, operational information, environmental conditions, and predictive assessment tools have gradually replaced traditional reactive maintenance approaches in pipeline integrity management (API, 2019; Khan et al., 2021). Because early detection of risks affecting the pipeline system is essential for efficient maintenance, risk assessment, and mitigation options, hazard identification is a key component of this process.

Hazard identification is the methodical identification, categorization, and recording of elements that may lead to pipeline failure or damage. Time-dependent risks include internal and exterior corrosion, material deterioration, erosion, fatigue, and coating deterioration are examples of these hazards. Third-party interference, unintentional excavation, natural disasters, sabotage, unauthorized connections, and intentional damage are examples of time-independent hazards (Khan et al., 2021). Because corrosion damages pipeline materials gradually and may go undetected until the problem becomes significant, it continues to be one of the most persistent risks. The rate and severity of corrosion are influenced by a number of factors, including soil condition, moisture, temperature, coating performance, cathodic protection, and product features (Ossai, Boswell, & Davies, 2015; Bhandari et al., 2015). Furthermore, farming, building, encroachment, excavation, and unauthorized access are all activities that can physically harm pipelines and raise the risk of leaks or ruptures within pipeline right-of-way locations.

Failure probability and consequence assessment are strongly related to hazard identification. Pipeline operators can analyze potential effects for people, property, ecosystems, and business operations, as well as anticipated failure mechanisms and probability of occurrence, once hazards have been identified. Operators can prioritize high-risk pipeline segments and more efficiently allocate maintenance resources thanks to risk-based integrity management, which takes into account both the probability of failure and the seriousness of its repercussions (Khan et al., 2021). The prompt detection of corrosion, cracking, wall thinning, deformation, and leakage is further supported by inspection and monitoring technologies like in-line inspection, ultrasonic testing, leak detection systems, pressure monitoring, sensors, geographic information systems, and digital analytics (Mohitpour et al., 2010; Xie & Tian, 2018).

Because to aged infrastructure, corrosion, vandalism, illegal tapping, poor maintenance, encroachment, and lax enforcement of safety standards, pipeline integrity is still a serious concern in Nigeria. These issues are especially important in the Niger Delta, where pipeline failures have resulted in product losses, livelihood losses, pollution of farmlands and water bodies, and worries about public safety (Onuoha, 2008; Ite et al., 2013; UNEP, 2011). An essential route for the transportation of petroleum products throughout southeast Nigeria is the Port Harcourt–Osisioma right-of-way in the states of Rivers and Abia. However, the corridor's integrity could be jeopardized by operational, environmental, technical, and human-related risks. Hazard identification procedures in Nigeria are frequently hampered by a lack of data, insufficient technological capability, lax regulatory enforcement, and a reliance on reactive measures following pipeline incidents, despite the growing global adoption of risk-based pipeline integrity management. This makes it necessary to evaluate how systematic hazard detection can lead to better pipeline integrity results.

LITERATURE REVIEW

From traditional periodic inspection and corrective repair, pipeline integrity management has evolved into a risk-based system that identifies, assesses, prioritizes, and controls vulnerabilities before they cause failure (American Petroleum Institute [API], 2019; Khan et al., 2021). Because pipeline failures can result in product loss, operational disruption, fire outbreaks, explosions, environmental contamination, financial losses, and dangers to public safety, this strategy is crucial because it entails the methodical identification, recording and assessment of circumstances, occurrences or actions that have the potential to harm a pipeline, hazard identification is a crucial part of pipeline integrity management. It offers the foundation for figuring out potential failure mechanisms, locating susceptible pipeline segments, calculating the likelihood of failure, and choosing appropriate preventative or remedial actions. Hazard identification is essential to risk-based integrity management because pipeline operators cannot properly evaluate or handle unidentified threats.

Khan et al. (2021) stated that the integration of hazard identification, failure-probability assessment, consequence analysis, monitoring, and mitigation strategies is necessary for efficient pipeline integrity management. Operators should therefore prioritize inspection and maintenance tasks in places where failure is more likely to occur or where the consequences of failure could be severe when dangers are promptly identified. Eke's (2023) study on casual dockworkers in Nigerian ports, which discovered that physically demanding work conditions and occupational risks contributed to a high prevalence of back pain among workers, is consistent with this emphasis on early detection and prevention. The study emphasized the necessity of worker training, safe work practices, ergonomic interventions, sufficient rest periods, and more robust enforcement of occupational health and safety regulations. Eke's (2023) study supported the more general idea that proactive hazard identification, safety training, and prompt control measures are crucial for preventing harm, protecting workers, and enhancing the safety of critical infrastructure operations, even though it concentrated on port workers rather than pipeline systems.

One of the most frequent risks to pipeline integrity is technical hazards. Internal and exterior corrosion, metal loss, cracking, coating deterioration, faulty welds, material fatigue, denting, and stress from pressure are some of these. Because corrosion progressively affects pipeline walls and may go unnoticed until the afflicted portion can no longer handle operational pressure, it is especially significant. While external corrosion may be impacted by soil properties, moisture, salts, coating failure, and insufficient cathodic protection, internal corrosion may be caused by water content, microorganisms, pressure, temperature, and the chemical characteristics of transported petroleum products (Bhandari et al., 2015; Ossai et al., 2015). According to Ahammed and Melchers (1996) and Zhou (2011), the likelihood of pipeline failure over time is influenced by corrosion flaws, material properties, operating pressure, and defect shape. Therefore, to stop leaks and ruptures, corrosion monitoring and early defect detection are essential.

Additionally, during design, fabrication, construction, installation, or commissioning, pipeline dangers may arise. When combined with corrosion, ground movement, variable pressure, or external loading, poor welding, inappropriate pipe materials, defective joints, shallow burial depth, insufficient pipe support, and structural deterioration can become major risks. Because of these risks, precise design, inspection, and repair records are crucial for efficient integrity management. In order to prevent deterioration and guarantee the safe functioning of oil and gas pipelines, Iqbal et al. (2017) noted that inspection and maintenance programs are crucial. In a similar vein, Kishawy and Gabbar (2010) contended that in order to lower the probability of failure across the pipeline life cycle, pipeline integrity management should integrate inspection, assessment, maintenance, and repair procedures.

Additional concerns include human activity and external intervention, especially along pipeline rights-of-way. Even when the pipeline material is physically sound, unexpected pipeline damage can result from excavation, farming, road construction, heavy equipment movement, illegal construction, encroachment, unauthorized access, illegal tapping, oil theft, and sabotage. Land-use activities and human behavior should be considered in pipeline risk assessment, as Liang et al. (2012) showed that third-party interference may be evaluated utilizing fault-tree-based methodologies and risk-classification approaches. Economic losses, insecurity, product theft, environmental damage, and disruption of the petroleum supply have all been linked to pipeline vandalism and sabotage in Nigeria (Onuoha, 2008; Adishi et al., 2017). These risks demonstrate that pipeline integrity is a security, environmental, and community relations issue in addition to a technical one.

Pipeline integrity is further impacted by environmental factors, particularly when pipeline routes pass through wetlands, flood-prone areas, farmlands, populated areas, and regions with unstable soil. Pipelines may be exposed, soil support may be weakened, coatings may be compromised, or stress may result in deformation and cracking due to flooding, erosion, subsidence, soil movement, vegetation development, and altered drainage patterns. Petroleum contamination has seriously harmed the ecosystem in the Niger Delta, disrupting agricultural livelihoods and degrading soil and water resources (Ite et al., 2013; United Nations ecosystem Programme [UNEP], 2011). The environmental significance of preserving pipeline integrity within the research region was highlighted by Elenwo and Anyanwu's (2017) report that oil pollution along the pipeline right-of-way at Osisioma Ngwa, Abia State, damaged soil properties.

Hazard identification supports pipeline integrity by enabling early detection and timely response. When threats are identified, pertinent actions that may be taken include in-line inspection, pressure reduction, corrosion control, repair, replacement, improved surveillance, access restrictions, emergency planning, and communication with host populations. In-line inspection technologies, such as magnetic flux leakage and ultrasonic testing, can detect corrosion, metal loss, cracks, dents, deformation, and wall-thickness reduction without halting pipeline operations (Xie & Tian, 2018). Sensor-based and predictive techniques can also improve defect identification; for example, El-Abbasy et al. (2014) found that artificial neural-network models supported by inspection data could predict the condition of offshore oil and gas pipelines.

METHODOLOGY

In order to investigate the role of hazard identification in guaranteeing pipeline integrity along the Port Harcourt–Osisioma right-of-way in Rivers and Abia States, Nigeria, this study used a cross-sectional survey design. 150 informed respondents from each of the stakeholder groups were chosen using stratified and purposeful sampling approaches. Because the corridor is strategically significant for the transfer of petroleum products and is vulnerable to risks including corrosion, vandalism, illegal tapping, encroachment, flooding, operational failures, and other technical and environmental challenges, the research area was chosen. A standardized questionnaire including demographic data and Likert-scale statements about pipeline integrity and hazard identification was used to gather data. Hazard identification was measured through early threat detection, hazard-assessment coverage, detection-system effectiveness, corrosion monitoring, surveillance, and community reporting, while pipeline integrity was measured through leak prevention, reduced pipeline incidents, corrosion control, operational continuity, timely maintenance, and resistance to external interference. The instrument was validated by relevant experts and pilot-tested for reliability using Cronbach's alpha. Data were analysed using frequencies, percentages, mean scores, and standard deviations, while simple linear regression was used to test the effect of hazard identification on pipeline integrity at the 0.05 significance level.

RESULTS AND ANALYSIS

Table 1 presents the summary of questionnaire administration and retrieval, which is an important indicator of the quality and reliability of the data collected for the study. A total of 150 questionnaires were distributed to respondents representing various stakeholder groups in pipeline management, accounting for 100% distribution. Out of these, 148 questionnaires were successfully retrieved, representing a very high response rate of 98.7%. This indicates strong engagement and willingness of respondents to participate in the study, which enhances the credibility of the data collected. Only 2 questionnaires (1.3%) were not retrieved, which is negligible and does not significantly affect the representativeness of the sample. Furthermore, all 148 retrieved questionnaires were deemed valid and suitable for analysis, also representing 98.7% of the total distributed instruments. This implies that there were no cases of incomplete or unusable responses, which strengthens the validity and reliability of the dataset. A response rate of this magnitude is considered excellent in survey research and falls well above the minimum threshold recommended in social science studies for generalization. Therefore, the high retrieval and validity rate confirms that the findings derived from the study are robust, reliable, and capable of providing meaningful insights into pipeline risk assessment and integrity management within the study area.

Table 1: Questionnaire Administration and Retrieval Result

Activity	Frequency	Percentage (%)
Distributed	150	100.0
Retrieved	148	98.7
Not Retrieved	02	1.3
Valid for Analysis	148	98.7

Source: Survey Data (2026)

Table 2: Responses on Hazard Identification Statements (N = 148)

Statement	SA	A	U	D	SD
Pipeline operators consistently identify hazards early	42 (28.38%)	57 (38.51%)	41 (27.70%)	7 (4.73%)	1 (0.68%)
Hazard identification is comprehensive	40 (27.03%)	47 (31.76%)	48 (32.43%)	13 (8.78%)	0 (0.00%)
Detection systems are effective	38 (25.68%)	56 (37.84%)	39 (26.35%)	12 (8.11%)	3 (2.03%)
Community monitoring improves detection	42 (28.38%)	56 (37.84%)	39 (26.35%)	11 (7.43%)	0 (0.00%)

Table 2 presents the responses of 148 respondents on hazard identification practices and their influence on pipeline integrity management along the Port Harcourt–Osisioma right-of-way. The findings indicate a generally positive perception of hazard identification effectiveness among pipeline stakeholders. For the first statement, "Pipeline operators consistently identify hazards early," 66.89% of respondents agreed or strongly agreed, while only 5.41% disagreed, suggesting that early hazard detection is moderately practiced within the study area. However, 27.70% remained undecided, which may indicate inconsistency in implementation or limited awareness among some stakeholders.

For the second statement, "Hazard identification is comprehensive," 58.79% of respondents expressed agreement, while 32.43% were undecided and 8.78% disagreed. This relatively high level of uncertainty suggests that although hazard identification mechanisms exist, their coverage may not be fully inclusive of all risk sources such as environmental and human-induced threats. Similarly, for the third statement, "Detection systems are effective," 63.52% of respondents agreed or strongly agreed, while 26.35% remained neutral and 10.14% disagreed. This indicates that while technological and procedural systems such as sensors and inspections are generally perceived as effective, there are still concerns regarding their consistency and reliability in practice.

Furthermore, the fourth statement, "Community monitoring improves detection," recorded the highest level of agreement, with 66.22% of respondents agreeing or strongly agreeing. This highlights the perceived importance of community participation in enhancing pipeline surveillance and early hazard detection in the region. Hence, the results suggest that hazard identification has a positive but not fully optimized role in pipeline integrity management. The presence of notable undecided responses across all items implies gaps in implementation consistency, integration of detection systems, and stakeholder engagement, which may limit the overall effectiveness of hazard identification strategies in ensuring pipeline safety.

CONCLUSION AND RECOMMENDATIONS

According to the study's findings, pipeline integrity along the Port Harcourt–Osisioma right-of-way in Rivers and Abia States is positively and significantly impacted by hazard identification. The results show that while most stakeholders acknowledge the importance of early hazard detection, efficient detection systems, and community monitoring in preventing pipeline failures, a sizable percentage of respondents were unsure, indicating that hazard identification procedures are not yet completely thorough, consistent, or sufficiently integrated throughout the pipeline corridor. Safe pipeline operation is nevertheless threatened by risks like corrosion, vandalism, illegal tapping, encroachment, flooding, poor maintenance, and third-party involvement.

Therefore, it is advised that pipeline operators increase the use of in-line inspection tools, corrosion-monitoring systems, pressure sensors, leak-detection technology, drones, and right-of-way surveillance, as well as reinforce routine risk-based hazard assessments. Additionally, operators should prioritize high-risk pipeline segments for intervention, keep up-to-date inspection and maintenance records, and quickly fix any flaws found. In addition to enforcing safety regulations pertaining to encroachment, excavation, unauthorized connections, and pipeline protection, regulatory bodies should enhance compliance monitoring. To enhance the early reporting of suspicious activities, leaks, damaged markers, and environmental changes along the right-of-way, pipeline operators should also set up organized community-engagement and reporting mechanisms, such as community surveillance partnerships and awareness campaigns.

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