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Enhancing Oil Pipeline Surveillance in Niger Delta

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ABSTRACT

Nigeria's Niger Delta oil infrastructure remains a critical economic backbone of the country. However, the oil infrastructure faces serious security challenges. This paper investigates challenges to pipeline surveillance and facility integrity in Niger Delta. It details serious crude theft through aping and artisanal refining, leading to severe economic loss, compromised infrastructure integrity, and severe environmental degradation. It is evident that current surveillance efforts cannot adequately secure the oil pipeline. There is evidence of corruption, technological constraints, and coordination failures that inhibit effective oil pipeline surveillance. Based on the lessons from successful community-based initiatives, current failures in rapid response systems, and insights from global oil-producing regions, the paper proposes a holistic approach that combines advanced technological tools, strengthening institutional coordination and formalizing community engagement. Also, legal reforms should help define roles and hinder criminal actors.

Keywords: *Pipeline, surveillance, crude theft, infrastructure integrity, environmental degradation*

Background and Significance

Nigeria's oil infrastructure remains a critical economic backbone of the country. Crude oil production and export contribute about 80 percent of the government's revenue. It also contributes to 90 percent of the country's foreign exchange earnings (Usman, 2021). The extensive oil infrastructure comprises pipelines critical for transporting crude oil from multiple oil fields to export terminals and refineries. The Niger Delta region remains a key strategic oil-producing region for Nigeria. The area spans about 70,000 km2 with immense gas and oil deposits. Hence, it holds important strategic importance as a direct pillar of Nigeria's economy (Agomuoh et al., 2021). Unfortunately, despite the importance of the Niger Delta and its oil infrastructure in the national economy, the region faces serious challenges, including socioeconomic underdevelopment, environmental degradation, and pervasive poverty. Also, the pipeline, crucial for crude oil transportation, is often vulnerable to widespread sabotage and crude oil theft that results in operational hazards and economic losses.

The scale of crude oil theft in the Niger Delta is serious. The impact is vast economic losses, severe environmental degradation, and significant operational risks to oil infrastructure. Nigeria has experienced severe financial losses though old theft between 2019 and 2022. The theft escalated from $2.1 billion in 2019 and $22.4 billion in 2022 (Dimkpa et al., 2023). Besides, monthly losses attributed to pipeline vandalism and oil theft are about $700 million, putting a serious dent in Nigeria's national economy. Illicit activities such as unauthorized artisanal refining and aping result in extensive pollution as hydrocarbons contaminate water bodies and soil, destroying vegetation. The environmental destruction threatens biodiversity, diminishes food security, and negatively affects human health (Amakama et al., 2021). It further impoverishes communities relying on agriculture and fishing in the region. In addition, crude oil theft via vandalism compromises pipeline integrity, resulting in corrosion, explosions and leaks that increase disruption frequencies and oil production downtimes that result in a financial burden on oil companies.

Problem Statement

While there have been surveillance efforts on the pipeline infrastructure, threats persist. They compromise the operational safety and integrity of the pipeline. Sabotage and vandalism are still the primary causes of pipeline failure in the Niger Delta. They contribute to infrastructure corrosion and aging (Agomuoh et al., 2021). The current surveillance systems are not effective because of their technological limitation, including inadequate coverage in challenging terrain such as dense forests and swamps. The surveillance system is also hampered by the high cost of advanced tools (Nwozor et al., 2023). In addition, system issues such as pervasive corruption within surveillance management and inadequate coordination among oil companies and security agencies minimize the efficacy of the surveillance strategies, including detection and response. Furthermore, lack or inadequate informal community engagement further worsens the identified vulnerabilities in the surveillance, hampering timely detection and prevention of illicit activities along oil pipelines in the Delta region (Nwozor et al., 2023). Therefore, the persistence of theft and sabotage necessitates urgent and holistic intervention to safeguard Niger's oil assets.

Objectives

The paper aims to analyze lessons learned from Niger Delta crude theft monitoring and response and use the insights to recommend enhanced strategies for pipeline surveillance and integrity management. Improved strategies will help secure the pipelines and other related infrastructures.

3. Contextual Overview

Niger Delta has a pipeline network that spans more than 5,000 km, with 41 percent of the pipeline being over 30 years old. Most pipelines were built between the 1960s and 1980 and constructed from API 5L steel and jointed by girth welds. Also, the pipelines are made of materials such as DNV-OS-F101 to withstand challenging environmental conditions in the Niger Delta. The pipelines traverse river crossings and swampy soils and landmass of the nine coastal states in Nigeria to cover about 70,000 km2. The infrastructure includes the Trans Forcados and Trans Niger pipelines. The entire pipeline infrastructure connects various oil fields to processing facilities, depots, and export terminals, ensuring an operational flow of Nigeria's oil supply chain. However, most of the pipelines in the Niger Delta are buried underground with no leak-detection systems, making undetected breaches common (Agomuoh et al., 2021). In less than 200 kilometers of the Trans-Niger Pipeline, there were 295 illegal connections in 2022, which caused a deep in daily oil output to below a million per day from 1.8 million barrels a day (Slay, 2025).

The extensive Niger Delta pipeline infrastructure is severely vulnerable due to a combination of environmental and socioeconomic factors. While most of the pipelines are laid underground, the region's aggressive soil, characterized by shallow water tables and high moisture, significantly increases pipeline corrosion risks and structural failures. A survey confirms that pipelines immersed in the Niger Delta's polluted water bodies are significantly corroded with high corrosion rates. The pipeline is exposed to anthropogenic pollutants (Olabisi & Chukwuka, 2020). The physicochemical properties of the soil include pH, moisture, redox potential, and chloride content that further exacerbate the corrosion of the metallic pipelines. In addition, socioeconomic issues and security challenges expose the pipelines in Niger Delta to crude oil theft through vandalism and tapping. The activities result in leaks, bursts, and explosions that cause structural weaknesses that increase operational risks and, subsequently, economic losses and environmental damages (Agomuoh et al., 2021). Therefore, the combination of a corrosive environment and human-caused damages highlights the urgent need to enhance surveillance.

Nature and Dynamics of Crude Theft

The crude oil theft method in Nigeria's Niger Dela is characterized by a range of techniques. The techniques evolve in complexity and scale. Illegal tapping is the most common. It entails bypassing oil pipelines to covertly siphon oil. Criminals drill illegal holes directly into active pipelines and tap oil into barges, trucks, or jerrycans (Mallo, 2024). The tapping operations often happen in inaccessible areas such as dense swamps, making detection and response challenging. After tapping, the stolen crude oil is transported through clandestine artisanal refineries.

Bypassing is another oil theft strategy used by criminals. It entails the installation of unauthorized connections or orifices, always via hot tapping or cold tapping. Hot tapping involves welding while the pipeline is active, while cold tapping is installing fittings without welding to divert crude oil without alerting operators via pressure drop (Agomuoh et al., 2021). The strategy complicates early detection. The artisanal refineries form a serious part of the illicit economy, operating unregulated small-scale processing that helps minimize the stolen crude oil. The criminal networks have international linkages, making oil theft a syndicate enterprise and operating a formal business. According to The Nigerian National Petroleum Company Limited (NNPCL), there were 619 incidents of crude oil theft between the months of December 2023 and March 2024 through 32 illegal connections and 25 pipeline vandalism incidents (Obi et al., 2021). Corruption and complicity of institutional actors are sustaining the criminality. The criminal actors include militants, complicit security personnel, black market syndicates, and community individuals.

Regulatory and Security Framework

Nigeria's regulatory and security framework for protecting the pipelines is multifaceted but not significantly effective. The Nigerian National Petroleum Corporation (NNPC), as a state monopoly, has the primary responsibility of managing and maintaining pipelines as well as ensuring operational security. NNPC collaborates with security agencies to fulfill its security mandate. It also hosts communities, involving them in safeguarding the pipeline infrastructure from vandalism, theft, and sabotage. Security responses fall to a patchwork of federal and state agencies—Army, Navy, and NPoS. Also, the Presidential Amnesty Programme partly funds pipeline-surveillance contracts with ex-militants (Panle, 2024). Unfortunately, though the statutory frameworks assign critical responsibilities to ensure pipeline protection in Niger Delta is always hindered by infrastructural vulnerabilities, inadequate funding, overlapping mandates, and the complex socio-political landscape of the Niger Delta region.

4. Surveillance Strategies and Limitations

The multifaceted surveillance system is apparent in the Niger Delta. The system integrates physical patrols, community policing, Supervisory Control and Data Acquisition (SCADA) systems, and remote and drone and sensing technologies to enhance pipeline infrastructure monitoring and protection. The physical patrols involve the security personnel consistently surveilling along the pipeline routes to identify and respond to threats. Limitations of physical security patrol are fatigue, error judgment, and restricted vision caused by the terrain. Therefore, patrolling personnel are not efficient in detecting and responding to vandalism or tapping incidents.

Community policing and community-based pipeline surveillance are becoming a critical aspect of pipeline security. The strategy leverages indigenous knowledge and local presence to foster cooperation with security personnel and enhance surveillance. Also, the use of advanced technologies such as

drones and remote sensing offers flexible, high-resolution, and real-time monitoring capabilities across inaccessible terrains. The military Unmanned Aerial Vehicles (UAVs) equipped with multispectral and hyperspectral sensors are used to detect leaks, third-party interferences, corrosion, and illegal refining activities, supporting prompt and accurate response efforts.

The SCADA systems play a serious role in surveillance activities. SCADA systems are computer control systems for monitoring and controlling geographically dispersed assets, usually scattered over thousands of miles. The system does not offer complete control but rather a supervisory level of control. It offers real-time pipeline monitoring by integrating sensors in the pipeline to detect anomalies such as pressure drops and oil leakage in real-time.

Limitations and Gaps

The current surveillance systems for monitoring oil infrastructure in Niger Delta have multiple limitations and gaps, hindering prevention of oil theft. Besides employing technology, the constraints are apparent, especially in relation to deployment and maintenance costs hindering adequate surveillance in challenging terrains such as dense forests and swamps, which offer good cover for criminals.

a) Coordination Failure

Coordination failure is a significant contributor to weak surveillance in Niger Delta. It is characterized by overlapping and unclear mandates among entities and bodies, including oil companies, security agencies, and private contractors. The high organizational fragmentation is responsible for inefficiencies, friction among stakeholders and duplication efforts. The result is poorly streamlined intelligence sharing and prompt response capabilities for pipeline threats. Therefore, the lack of a unified strategy undermines a collective capacity to address pipeline insecurity accordingly.

b) Corruption

Corruption is a serious hindrance to oil pipeline security in Niger Dela. There is severe corruption within surveillance and security management contracts has compromised the operational integrity. Evidence highlights how fraudulent practices undermine pipeline security. O'Farrell et al. (2025) confirm that insider collaboration resulted in the theft of 13 million barrels of crude oil that caused ecological damage, including the annual loss of 5,644 hectares of mangrove forests. Persistent corruption is compromising local security networks that enable unending illegal sabotage and bunkering. Therefore, the systemic failure highlights the need for transparent security surveillance.

c) Inadequate Community Engagement

Community engagement remains ineffective due to inconsistency and not addressing underlying issues affecting them. Integration of community into the surveillance initiatives is not formalized, resulting in underutilization of local presence and knowledge. It results in reduced trust-based relationships critical for strong security surveillance. In addition, the need to survive pushes local communities to directly or indirectly engage in oil theft. Most engage in the illicit trade to survive because the government neglects the Delta region. High unemployment rates and insufficient social services are fueling illicit trade amidst the proliferation of light and small weapons (Sekibo & Nte, 2022). Therefore, formal community engagement programs should address communities' economic needs.

5. Facility Integrity Challenges

Impact of Crude Theft on Infrastructure

Crude oil theft adversely impacts the integrity of pipeline infrastructure. The effect includes widespread leaks, corrosion, and dangerous explosions that disrupt the overall operation. Illegal tapping and vandalism cause physical damage; whereby drilling and unauthorized bypasses cause structural weaknesses that increase the risk of explosions. According to Izionworu et al. (2025), Vandalism-instigated corrosion happens after intentional damage. The scratches during vandalism remove the protection layer, exposing the metal to corrosive environments, including soil and pollutants, which accelerate corrosion. In 2015, a major pipeline corrosion exacerbated by sabotage resulted in a pipeline rupture in Niger Delta. Izionworu et al. (2025) confirm that criminals use chemicals during pipeline vandalism, consistently compromising the integrity of oil pipelines. Finally, the compromised pipeline is associated with pipeline explosions that result in loss of lives, oil spills that damage the environment and aquatic lives, extensive property destruction, and financial loss.

Integrity Monitoring Systems

Players are using a blend of traditional methods and digital technologies for pipeline structural m health monitoring. Traditional surveillance entails physical patrols and community-based policing to complement technological approaches. Players use Wireless Sensor Networks (WSNs) for detecting and providing accurate real-time location of potential weaknesses. The system utilizes low power, besides being cost-effective. WSNs provide continuous data on leak detection using flow rate and pressure sensors to identify anomalies (Ezeja & Nwobi, 2024). Also, magnetic flux leakage (MFL) and fiber optic sensors have often been deployed to assess structural tampering and weaknesses (Bango, 2023). The limitation of the advanced monitoring systems is that their integrity is compromised by factors such as inadequate sensor coverage, coordination frailties among agencies, and Niger Dela's harsh environmental condition.

Gaps in Predictive Maintenance and Risk Management

The advanced predictive and risk management for pipeline integrity have serious gaps. The primary issue is the lack of real-time data and standard analytics platforms, impeding timely and accurate identification and forecasting of threats such as cracks, corrosion, or mechanical damage. Currently, there are limited robust predictive models to implement in a unique environment with operational variabilities, such as the Niger Delta, which has high corrosive conditions. There is also limited implementation of AI-driven tools to enhance early detection and maximize maintenance schedules. Besides, there are limited, accurate data necessary for predictive models (Zacchaeus et al., 2023). Therefore, quality data collection and stakeholder collaboration are necessary for enhancing the effectiveness of AI models and maximizing predictive maintenance and risk management.

6. Case Studies and Lessons Learned

Successful Community-Based Surveillance Programs

Despite the challenges in the surveillance and monitoring strategies in Niger Delta, stakeholders can build on successful community-based programs to secure oil pipelines. For example, Infrastructure Nigeria Limited (PINL) continues to hold a community engagement program in Yenagoa, Bayelsa State, to enhance surveillance of oil infrastructure. The company recruits local surveillance guards, provides economic empowerment programs, holds monthly stakeholder meetings, and promptly pays stipends. The oil company reports that community surveillance has resulted in the prosecution of more than 100 individuals involved in pipeline vandalism and oil theft, with 15 remanded at the Port Harcourt prison. The organization complements community surveillance with military patrols, resulting in a significant decline in oil theft and pipeline vandalism on the Trans Niger Pipeline corridor. Collaboration with communities such as Diebu Creek and Gbanraun in Bayelsa State improved uninterrupted oil flow to the Bonny Terminal (Abang, 2025). Therefore, PINL community engagement programs highlight the success of community-based surveillance.

Failures in Early Warning and Rapid Response Systems

Case studies confirm the significant failure of early warning and rapid response systems for oil pipelines in the Niger Delta. Iwuoha (2021) confirmed that there are significant gaps in strategic security planning and capacity building for Nigeria's security agencies. The deficiencies include insufficient operational equipment, such as surveillance equipment such as speed boats, and communication devices. In addition, awarding pipeline surveillance contracts to private security companies always causes overlapping functions and inter-agency frictions, compromising coordination, which is essential for an early warning and rapid response (Iwuoha, 2021). Both community and oil companies agree that current early warning and rapid response systems are inadequate. Emelu et al. (2021) attribute the inefficiencies to insufficient surveillance technology, weak enforcement mechanisms, and inadequate community awareness. In addition, inadequate power support and insufficient human resources impede the functionality of early warning systems. Therefore, early warning and rapid response systems are failing due to a combination of factors.

Comparative Insights from Other Oil-Producing Regions

The early warning and rapid response systems (EWRRS) are adequate in major producing regions offering key lessons for stakeholders in Niger Delta. The Gulf of Mexico and the Middle have robust regulatory frameworks and advanced technology as well as robust institutional coordination. The Gulf of Mexico leverages satellite monitoring, automated sensors, and predictive modeling to detect oil spills, promoting prompt response. For example, the 2010 Deepwater Horizon spill was initially detected by an underwater camera that showed a damaged wellhead (Dong et al., 2022). In addition, the Gulf of Mexico and Saudi Arabia use advanced leak detection systems (LDS) that use real-time data analytics and real-time pipeline surveillance and emphasize predictive maintenance. They combine community-integrated surveillance with satellite surveillance. Norway's Petroleum Safety Authority uses automated leak detection systems for risk assessment and continuous maintenance. Canada utilizes geospatial intelligence and remote sensors to promptly detect pipeline stress and AI-driven diagnostics with drone surveillance (Al-Rbeawi, 2023). Conversely, Niger Delta relies on aging infrastructure and limited community engagement, causing delayed detection and responses to vandalism and spills.

7. Policy and Technical Recommendations

Integrated Surveillance Approach

An integrated surveillance approach is needed to ensure pipelike security and integrity in Niger Delta. It entails leveraging the strength of human intelligence and advanced surveillance tools to promote real-time monitoring and rapid response. Sensor networks, distributed acoustic sensing (DAS), and AI-driven anomaly detection algorithms ensure limited errors, heightened vision, and detection of vandalism, oil theft, spills, and structural integrity compromises (Wang et al., 2023). Therefore, a technical recommendation is incorporating artificial intelligence into the surveillance system.

Community Engagement and Ownership

Formal community security roles and community engagement programs are important in enhancing pipeline surveillance and security in Niger Delta. Besides giving communities formalized security roles, empowering and engaging them regularly promotes genuine collaboration that helps minimize security challenges (Elisha & Golden, 2022). Supporting Community-based vigilante groups through community empowerment initiatives reduces violence and enhances oil pipeline security. The community should be empowered through training and providing surveillance equipment while balancing flexibility and formal structure to promote genuine collaboration. According to Inimiesi and Obiene (2024), neighborhood-based initiatives are central to providing information to law enforcement in Nembe City. Therefore, integrating community engagement and formalized community security roles with other surveillance and protection strategies enables rapid intelligence sharing, preventing oil pipelines from sabotage and vandalism.

Strengthening Institutional Coordination

Weak strategic security and poorly defined roles hinder proper surveillance and response to oil thieves. There is significant overlap and conflict among multiple agencies protecting oil pipelines in the Niger Delta region. Developing a multiagency framework based on mandate clarity, reducing duplication, and promoting shared security goals will enhance institutional coordination. In addition, effective leadership, coordinated communication, and a high level of trust among member agencies can help collaborating agencies address the complex security challenges in Niger Delta. There should be standardized operational procedures, consistent training, and improvements. Also, institutional coordination should integrate local communities into security efforts based on formal agreements, and private security contractors should be subjected to rigorous regulation and oversight to enhance accountability. Robust legal frameworks are necessary to legitimize multiagency cooperation (Sekibo & Nte, 2022). Finally, institutions should leverage advanced technology to enhance coordinated rapid response capabilities.

Investments in Predictive Maintenance Tools

Investing in advanced predictive maintenance tools is necessary to enhance oil pipeline security, integrity, safety, and operational efficiency. While Non-Destructive Testing (NDT) methods such as electromagnetic inspection, intelligent pigging, and ultrasonic testing are vital practices, they are limiting unless they are supplemented by artificial intelligence (Odor et al., 2024). AI-based anomaly detection, corrosion monitoring systems, and data analytics can predict potential failures and enable proactive maintenance. For example, PETRONAS' Pipeline Predictive Analytics for corrosion integrates real-time operational data, inspection reports, and cathodic protection data with machine learning to predict corrosion on offshore and onshore pipelines (Tariq et al., 2021). Therefore, AI-based anomaly detection and corrosion monitoring systems allow pipeline operators to optimize maintenance schedules, minimizing costs related to disruption and unscheduled downtime. They are effective for challenging environments such Niger Delta, which needs sophisticated surveillance and maintenance strategies.

Legal and Enforcement Reforms

Legal and enforcement reforms are needed to bolster oil pipeline security in Niger Delta. The current laws and regulations enacted by the Nigerian government face serious challenges in combating pipeline vandalism, crude oil theft, and illegal bunkering. While laws such as the Petroleum Production and Distribution (Anti-Sabotage) Act 2007 criminalize crude oil theft, enforcement efforts hinder the successful prosecution of offenders, limiting deterrence. Potential reforms include stringent penalties for oil theft and vandalism by including terrorism charges. Legislation should also define security roles to prevent role overlap and conflict between agencies and private contractors. The Petroleum Industry Act 2021 (PIA, 2021) is a recent structural reform describing responsibilities between upstream and downstream regulators (Okediya, 2021). However, the proposed reform does not address conflict of interest and lack of multiagency integrated roles. Therefore, legal reforms will be effective when complemented with genuine multiagency and community collaboration as well as sound governance practices.

8. Conclusion

Niger Delta's oil infrastructure faces serious threats, particularly crude oil theft and vandalism. The consequences include economic losses, operational risks, and spills that cause environmental damage. Contributing factors include poor surveillance and monitoring systems, coordination limitations among responsible agencies, inadequate community engagement, and corruption. Cude theft comprises oil pipeline integrity bay causing physical damage, exacerbating corrosion and causing explosions and leaks. There is a need to address surveillance and monitoring limitations by investing in modern surveillance systems, including AI-driven anomaly detection systems. Formal community-based surveillance programs and a coordinated multiagency approach are needed to enhance surveillance, monitoring, and response. Finally, law reforms should address overlapping roles that hinder surveillance and monitoring efforts in Niger Delta.

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