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Oil Spillage Monitoring in Nigeria and the Role of Remote Sensing - An Overview

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ABSTRACT

Oil spillage poses a persistent challenge in Nigeria most especially in oil-rich Niger Delta region, necessitating effective monitoring and mitigation measures. This study provides an overview of oil spill monitoring in Nigeria, emphasizing the pivotal role of remote sensing technology. Leveraging data from the NOSDRA Oil Spill Monitoring website, spanning 2016 to 2020, variations in spill occurrences among oil companies are analyzed. In 2016, a total of 42,741.25 barrels were spilled across 689 incidents, with NPDC emerging as the top spillage contributor. Similarly, 2017 witnessed 35,076.62 barrels spilled across 604 incidents, with NPDC and SPDC maintaining dominance. The trend continued in 2018, with SPDC recording the highest volume of spills among the top six contributing companies. However, in 2019, spillage increased, led by SPDC, followed closely by Heritage Energy Operational Services Limited and Aiteo. Conversely, 2020 saw a decrease in spillage, albeit SPDC retained its lead. These findings underscore the critical need for enhanced monitoring and regulatory enforcement to mitigate the environmental and socio-economic impacts of oil spills in Nigeria. However, proactive measures are needed to strengthen regulatory oversight, improve spill response capabilities, and promote transparency and accountability within the petroleum industry.

INTRODUCTION

In Nigeria, the effects of oil exploration are especially evident in the Niger Delta region. Decreased food productivity, harm to the subsistence economy, habitat distortion, outbreaks of epidemics, and overall social instability constitute just a few of the myriad adverse effects that crude oil exploitation has brought upon the Niger Delta (Onwurah *et al.*, 2007). According to a study conducted by the Nigerian Conservation Foundation in 2006, the estimate for oil spills, both onshore and offshore, over the past 50 years ranges from 9 to 13 million barrels, significantly jeopardizing the well-being of the populace (Nriagu, 2011). Onwurah *et al.* (2007) observed that a significant portion of oil spills that occurred on dry land between 1978 and 1979 in Nigeria affected farmlands, resulting in the loss of crops such as rice, maize, yams, cassava, and plantain. Similarly, findings from studies carried out by the United Nations Environmental Programme (UNEP) in 2011 in the Niger Delta indicate that residents are exposed to elevated levels of petroleum hydrocarbons in contaminated drinking water and outdoor air, posing a serious health threat (UNEP, 2011).

Recently, the availability of aerospace remote sensors with wide and repetitive coverage at low costs has provided Remote Sensing with an advantage in detecting and monitoring environmental changes on Earth (Uchegbulam & Ayolabi, 2013). The spatial resolution has improved and reached a level at which the quality of publicly available space-borne imagery rivals that of air-borne imagery (Jha *et al.*, 2008). Remote sensors have the capability to detect and control hydrocarbon spillage on various types of surfaces. Multi-temporal remote sensing images can furnish essential information necessary for modeling the spread of an oil spill, and GIS oil spill models can aid in cleanup operations and controlling the oil spill (Dahdouh-Guebas, 2002). Detecting oil spills through remote sensing frequently forms the basis for establishing the impact of oil pollution on near-shore areas, marshes, and mudflat ecosystems. Common techniques used for oil spill detection include image spectroscopy (Khanna *et al.*, 2013; Kokaly *et al.*, 2013) and field spectroscopy (Mishra *et al.*, 2012), broadband Vegetation Health Indices, narrowband vegetation indices, and more recently, airborne SAR polarimetry (Adamu *et al.*, 2015; Arellano *et al.*, 2015; Ramsey *et al.*, 2014; 2015). Results from satellite image processing, with a focus on vegetation health, are particularly valuable in assessing the impact of oil on terrestrial mangrove and swamp ecosystems, as well as delicate near-shore marsh vegetation (Adamu *et al.*, 2016; Mishra *et al.*, 2012; Onwurah *et al.*, 2007; Sun *et al.*, 2016; Zabbey and Uyi, 2014). Hence, this paper seeks to address the inadequacies in current oil spill monitoring methods in Nigeria and explore the potential of remote sensing technology to improve early detection, response, and mitigation efforts for environmental and socio-economic impacts.

LITERATURE REVIEW

The term 'Remote Sensing' broadly refers to the technique(s) used for gathering images or other data about an object without physical contact, utilizing electromagnetic energy radiation, interaction, and detection principles in analogue or digital formats.

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However, for the purpose of this discussion, only optical images captured by space-borne or air-borne sensors are considered (Dahdouh-Guebas, 2002; Muhammad, 2013). In recent times, Remote Sensing technology has seen increased utilization by scientists for describing and monitoring various systems on both local and global scales. This technology has progressed from simple visual imagery, such as panchromatic aerial photographs, to more complex multi/hyper spectral imagery (Dahdouh-Guebas, 2002).

Geographic Information Systems (Gis) and Remote Sensing (Rs) Studies in the Field of Oil Spills in Nigeria

Due to the significant number of oil spills in the Niger Delta, there has been a growing interest among researchers in utilizing Geographic Information Systems (GIS) and Remote Sensing (RS) to analyze the distribution of oil spills, understand the underlying causes, assess their detrimental effects on the natural landscape, evaluate environmental impacts, and develop risk and sensitivity models to mitigate the rapid degradation of vegetation in the region. A crucial area of research in the Niger Delta has focused on spills resulting from pipeline attacks, examining the connection between these incidents and the socio-economic conditions of the affected areas (Anifowese *et al.*, 2012). This research has provided a quantitative and regional exploration of the issue of oil pipeline vandalism in Nigeria by analyzing interdiction statistics, revealing a significant negative correlation between pipeline interdiction and poverty levels in the Niger Delta (Anifowese *et al.*, 2012). Additionally, Anifowese *et al.* (2012) investigated the spatial relationship between waterways and downstream pipelines to assess how pipeline interdiction has been addressed in Environmental Impact Assessments and identified vulnerable points on pipeline river crossings prone to oil spills, concluding that 115 pipeline river crossings are considered potential hazard locations requiring careful management. Kuenzer *et al.* (2014) conducted analyses on land cover changes, coastline dynamics, and the manifestation of oil exploitation activities between 1986 and 2013 in the Niger Delta, clearly highlighting the impacts of oil industry activities in the region. Furthermore, Oyehan *et al.* (2014) developed a GIS database of major oil spills in Rivers State, characterizing them in terms of volume, temporal occurrence, and spatial distribution, and proposed a management approach for oil spills based on GIS analysis.

Environmental Impact Studies Using Gis and Remote Sensing

Osei *et al.* (2006) utilized GIS and Remote Sensing tools to detect environmental degradation stemming from development activities along the coastal region of Southern Nigeria. Their findings unveiled significant environmental deterioration in the study area, attributed to factors such as increased human settlement, mixed forests, erosion, cropland expansion, intensified agriculture, as well as oil spillages and gas flaring, which have ravaged both the natural and human environment. Similarly, Twumasi & Merem (2016) conducted a study to evaluate the environmental impact of the oil industry on the Niger Delta by comparing Landsat satellite images from 1985 to 2000 using unsupervised classification techniques. Their results highlighted a decline in water bodies and mangrove forests, illustrating the impact of oil spills in the region.

Furthermore, Uchegbulam & Ayolabi (2013) investigated environmental degradation in the Western part of the Niger Delta. Employing NDVI analysis on Landsat images from 1987 and 2002, they concluded that the decrease in NDVI values between these dates indicated land degradation due to hydrocarbon exploration and human activities. Adoki (2013) also studied environmental degradation in the Niger Delta using NDVI analysis, revealing a decrease in vegetation cover, particularly mangrove trees, due to increased Oil and Gas industry activities.

Additionally, Wokocha *et al.* (2013) utilized remote sensing techniques and GIS to map vegetation land cover in Delta and Edo states of the Niger Delta region between 1990 and 1999. Their study, employing Landsat 4-5 data, showed a significant decline in vegetation cover during this period. Similarly, Orimoogunje & Ajibola (2013) evaluated changes in the land cover of the mangrove ecosystem in the Niger Delta between 1986 and 2008. They assessed the recovery time of mangrove vegetation from oil spill impacts and developed a GIS-based model for mangrove vegetation recovery. Their findings indicated a downward trend in mangrove vegetation recovery from 1986 to 2000, followed by an upward trend from 2000 to 2007 in the GIS-based model. For monitoring hydrocarbon leakage using remote sensing techniques, Adamu *et al.* (2013) analyzed spectral reflectance data from Landsat TM of vegetation exposed to hydrocarbons in mangrove and swamp vegetation areas. By comparing vegetation spectra between polluted and non-polluted sites and employing supervised classification, they mapped hydrocarbon-contaminated sites and observed stressed vegetation characterized by high reflectance in the visible region and lower reflectance in the near-infrared region, suggesting potential migration of hydrocarbons to the wider environment.

METHODOLOGY

The data utilized in this study were sourced from secondary data and publications from various entities, including the Nigerian government and its affiliated institutions, oil companies operating within the country, as well as local and international organizations. Government establishments such as the Department of Petroleum Resources (DPR), and the National Oil Spill Detection and Response Agency (NOSDRA) website served as key sources of information. Additionally, publications from prominent oil companies like Shell Petroleum

Development Company of Nigeria (SPDC), Nigeria Agip Oil Company (a subsidiary of ENI), among others, were accessed. These major oil companies have Joint Venture Agreements with the Government Oil Company (NNPC), and the publications from both government and local groups provided valuable insights for this study.

DISCUSSION

Overview of Oil Spillage in Nigerian

Petroleum industry activities in Nigeria have contributed significantly to environmental degradation in the oil-producing regions of the country (Nwankwoala & Nwaogu, 2009). Oil spills, defined as the release of liquid hydrocarbons, whether crude or refined oil, into the environment due to human activities (Adelana *et al.*, 2011), represent one of the major challenges faced by the oil industry in Nigeria. Consequently, the Niger Delta region has been identified as one of the most severely impacted areas globally (Nwankwoala & Nwaogu, 2009). With over 1,000 oil production wells and 47,000km of oil and gas pipelines (Ngobiri *et al.*, 2007), the Niger Delta grapples with serious environmental issues stemming from oil spill incidents. The region, plagued by frequent oil leaks from various oil facilities, has witnessed adverse effects such as compromised air quality, soil pollution, destruction of mangrove swamps and farmlands, contamination of drinking water sources, and fishing creeks (Orgi, 2001; Twumasi & Merem, 2016; Orimoogunje & Ajibola, 2013). These spills have inflicted substantial economic losses on local inhabitants, many of whom rely on fishing and subsistence farming for their livelihoods.

Moreover, petroleum fires resulting from ruptured pipelines and tankers have exacerbated the efficiency of oil spills, leading to catastrophic consequences for both humans and ecosystems (Emengini *et al.*, 2013). The prevalence of oil spills in the Niger Delta was a key factor in the region's inclusion among the ten most polluted places globally in 2013 by the Blacksmith Institute (Kuenzer *et al.*, 2014).

Consequently, Opukri & Ibaba (2008) concluded that oil spills, among other factors, have contributed to internal displacements in the Niger Delta, exacerbating poverty levels in the area. Despite ongoing efforts, oil spill incidents in Nigeria remain underreported (Ajide & Isaac, 2013). Estimates indicate that over 9,000 oil spill incidents occurred between 1976 and 2005, resulting in the release of more than three million barrels of oil into the Nigerian environment (Egberongbe *et al.*, 2006). The frequency of oil spill incidents has increased significantly in recent years, with the Nigerian National Petroleum Corporation (NNPC) reporting over 20,000 incidents in the transportation pipeline sector alone between 2006 and 2013 (NNPC, 2014). Additionally, the Department of Petroleum Resources in Nigeria reported that only 23% of the spilled oil between 1976 and 1996 was recovered from the environment (Nwilo & Badejo, 2006), with independent assessments estimating that over 115,000 barrels of oil are spilled into the Niger Delta environment annually (Ajide & Isaac, 2013).

Historically, the Niger Delta has experienced numerous major spills, resulting in significant quantities of spilled oil. For instance, in 1978, two oil spill disasters occurred in the Niger Delta: the first from GOCON's Escravos, resulting in a spill of 300,000 barrels of oil, and the second due to SPDC's Forcados Terminal tank failure, resulting in a spill of 580,000 barrels of oil. Subsequent years saw further incidents, including a Texaco Funiwa-5 blowout in 1980, resulting in a spill of about 400,000 barrels of oil, and an oil spill from the Abudu pipeline in 1982, which led to the release of approximately 19,000 barrels of oil. The impact continued with spills from Idoho in 1998 (40,000 barrels), Etiama in 2000 (11,000 barrels), and Ughelli in 2005 (10,000 barrels) (NNPC, 2014; Nwilo & Badejo, 2005).

Various factors contribute to oil spill incidents, including natural disasters such as landslides and earthquakes, operational failures such as poor maintenance and human errors, and vandalism aimed at oil theft or sabotage (Anifowose *et al.*, 2012). In Nigeria, vandalism of oil pipelines by local inhabitants is the primary and most serious cause of oil spills. Aging pipelines, oil blowouts from flow stations, and other operational failures also contribute to spill incidents (Nwilo & Badejo, 2005). Shell Petroleum Development Company (SPDC) reported that 73% of oil spill incidents at the company's facilities between 2008 and 2012 were due to vandalism (Shell, 2014). Furthermore, the Nigerian National Petroleum Corporation (NNPC) annual bulletin for 2013 indicated that out of 3,570 pipeline line breaks reported, 3,505 were attributed to vandalism, highlighting its significant role in oil spill incidents, potentially accounting for over 98.2% of incidents in 2013 (NNPC, 2014).

Table 1: Pipeline incidences in Nigeria between 2004 and 2013, and amount of vandalism and operational reasons for each year

Year	Total incidents	Operational	Vandalism	Operational percentage	Vandalism percentage
2004	971	76	895	7.8%	92.2%
2005	2258	21	2237	0.9%	99.1%
2006	3683	9	3674	0.2%	99.8%
2007	3244	20	3224	0.6%	99.4%
2008	2318	33	2285	1.4%	98.6%
2009	1480	27	1453	1.8%	98.2%

2010	860	24	836	2.8%	97.2%
2011	2787	19	2768	0.7%	99.3%
2012	2256	26	2230	1.2%	98.8%
2013	3570	65	3505	1.8%	98.2%

Source: NPPC, (2014).

Oil spills are a recurring issue in the country, with hundreds of incidents annually causing environmental damage and disrupting the lives of Niger Delta residents, as highlighted by Amnesty International. Between 2011 and 2018, Shell's operational area alone witnessed 1,010 spills, with figures such as 189 in 2011, 188 in 2012, and 181 in 2013 (Federal Republic of Nigeria, 2010; Amnesty International, 2013). Similarly, Nigeria Agip Oil Company (ENI) reported 351 spills in 2014, 196 in 2015, and 165 in 2016. On average, these two companies collectively recorded approximately five spills per week from 2011 to 2017. Notably, many smaller spills often go unreported, contributing to the significant volume of oil released into the environment. Amnesty International's 2018 study revealed that Shell and Nigeria Agip Oil Company alone spilled 21.7 million liters of oil, equivalent to 9 Olympic swimming pools, between 2011 and 2017. Shell's spills amounted to about 2.4 million liters in 2011, 3.8 million in 2012, and 3.4 million in 2013, while Nigeria Agip Oil Company spilled approximately 1.1 million liters in 2014 and 1.8 million in 2015.

Taking a nationwide perspective, considering all oil-producing companies, reveals the scale of the issue, with approximately 546 million gallons of oil (roughly 13.37 million barrels) spilled in Nigeria between 1958 and 2010, averaging about 257,142 barrels annually (UNDP, 2006; Francis *et al.*, 2011). This results in an average of around 650 spills annually, with approximately 18,855 barrels being spilled each year, highlighting the ongoing impact on affected areas and emphasizing the need for better monitoring and control measures. According to the UNEP report in 2011, the repercussions of oil spills persist long after the initial incident due to insufficient cleanup efforts. This situation is widespread, as evidenced by UNEP's findings in Ogoni land, where oil contamination continues to plague the environment despite the cessation of oil industry activities. As a result, the Niger Delta has earned the dubious distinction of being labeled by Watts and Zalik (2020) as "the most polluted place on the planet."

Table 2: Shows the situation from 2010 to 2018

Year	Number of Spills	Quantity of Oil Spilled (Barrels)
2010	537	17,658.10
2011	673	66,906.84
2012	844	17,526.37
2013	522	4,066.20
2014	1087	10,302.16
2015	753	32,756.87
2016	434	1,658.98
2017	429	9,097.05
2018	567	9,718.22
Total	5848	169,690.79

Source: Department of Petroleum Resources, (2018)

Oil Spill Monitoring and Control in Nigeria

The organizational structure for monitoring and controlling oil spills involves several key entities, including the Department of Petroleum Resources (DPR), the National Oil Spill Detection and Response Agency (NOSDRA), oil companies, and the communities residing in oil-producing areas and along oil and gas pipelines. DPR and NOSDRA primarily perform regulatory functions within the petroleum industry. DPR, established in 1970, oversees petroleum industry operations and ensures compliance with national and international standards regarding health, safety, and environmental regulations. Its functions include supervising industry operations, advising government on petroleum-related matters, processing applications for leases, licenses, and permits, and maintaining records on industry operations. On the other hand, NOSDRA, founded in 2006 with a focus on environmental responsibility, is the lead agency in managing oil spills in Nigeria. Its key functions include surveillance to ensure compliance with environmental regulations, receiving reports of oil spills, coordinating spill response activities, and overseeing the removal of hazardous substances. The Director General/Chief Executive Officer of NOSDRA serves as the "National Commander" of the National Oil Spill Contingency Plan, indicating the agency's pivotal role in spill management.

NOSDRA has developed a database utilizing geographical mapping to report and monitor oil spills, including incident reports and spill volumes. This database, accessible through the website (https://oilspillmonitor.ng), allows for tracking spills by each month. Results from 2016 to 2020 have revealed variations in spill occurrences among oil companies in Nigeria, with some companies being responsible for more spills than others. Detailed statistics on spill volumes, categorized by company and month, are available through this platform, facilitating informed decision-making and targeted intervention measures.

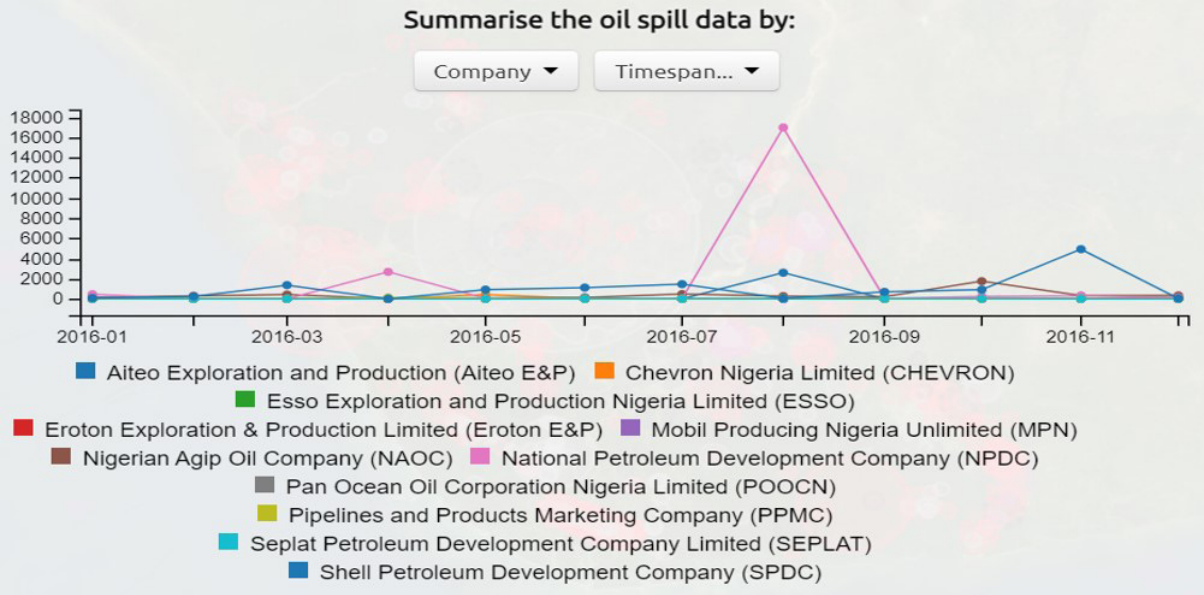

Figure 1: Barrels Oil Spill by Company and Months in 2016

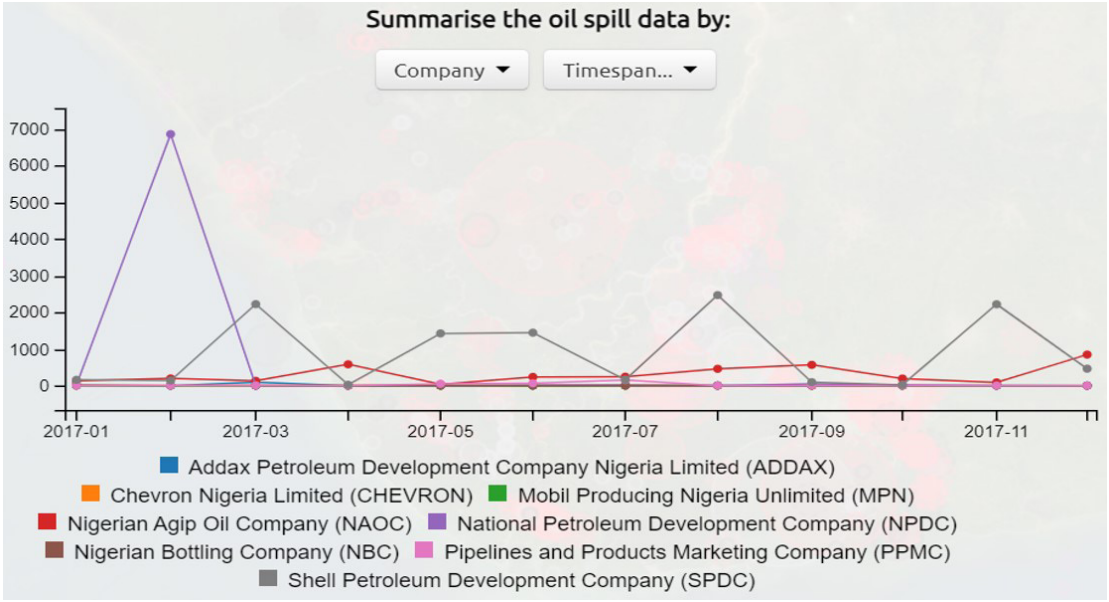

Figure 2: Barrels Oil Spill by Company and Months in 2017

The report obtained from the NOSDRA Oil Spill Monitoring website reveals that in the year 2016, a total of 42,741.25 barrels of oil were spilled across 689 incidents involving various companies. However, it was observed that the top six companies responsible for these spills were the National Petroleum Development Company (NPDC), Shell Petroleum Development Company (SPDC), Nigerian Agip Oil Company (NAOC), Aiteo Exploration and Production (Aiteo E&P), Heirs Holding Oil and Gas Limited (HHOG), with spillage reports of 20,893.57, 11,734.60, 4,441.04, 2,785.00, and 1,427.67 barrels respectively. These figures highlight NPDC as the company with the highest volume of oil spilled in the year 2016. Similarly, in 2017, a comparable trend was observed, with a total of 35,076.62 barrels spilled across 604 incidents by various companies. However, the top

five companies responsible for these spills were SPDC (10,834.68), NPDC (6,993.00), NewCross Exploration and Production (5,000.00), Aiteo E&P (4,300.00), NAOC (3,693.53), and Total Exploration and Production (1,887.29). This comparison indicates a decline in total oil spillage by these companies from 2016. Nonetheless, NPDC and SPDC remained the top oil spill companies in both years when compared to others.

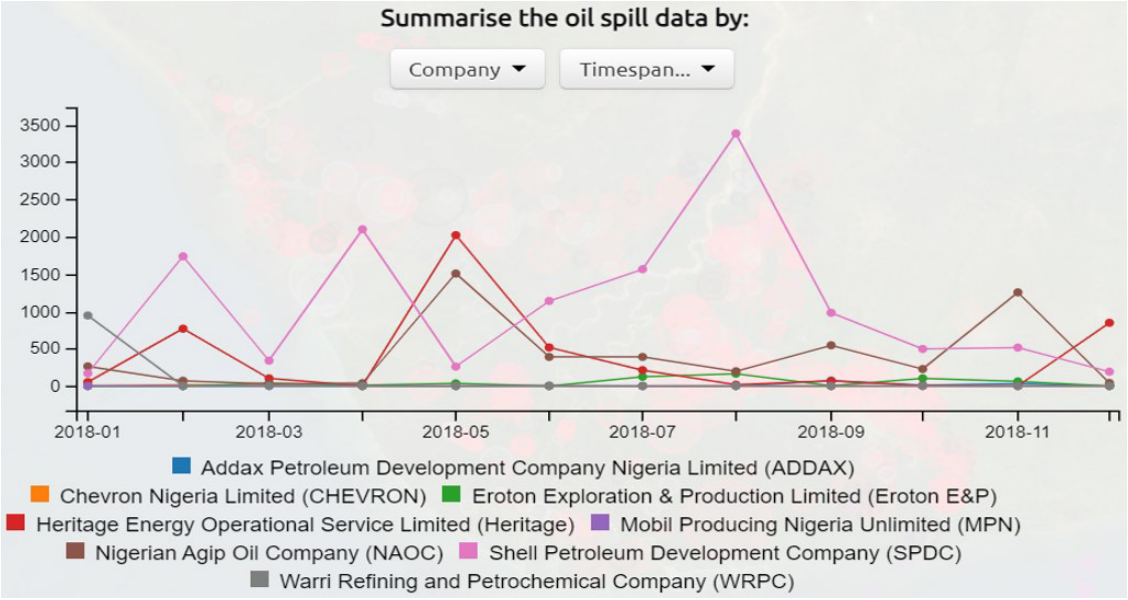

Figure 3: Barrels Oil Spill by Company and Months in 2018

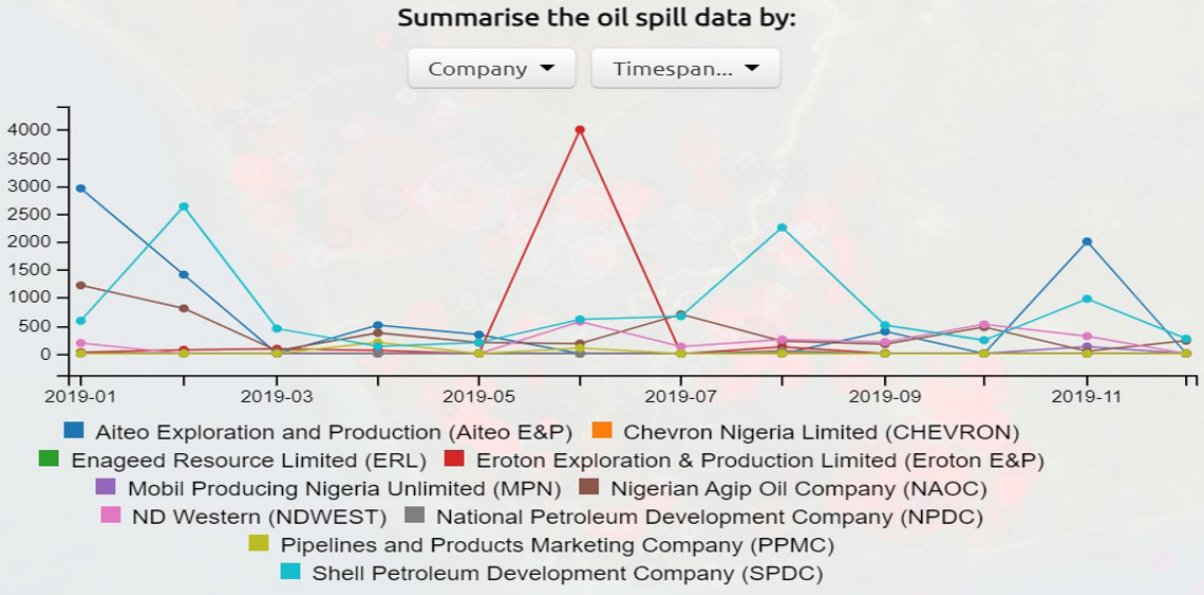

Figure 4: Barrels Oil Spill by Company and Months in 2019

The reports of barrels spilled by companies in the year 2018 totaled 28,827.29, with 716 incidents recorded. This marked an increase in the number of incidents compared to 2016 and 2017. However, Shell Petroleum Development Company (SPDC) recorded the highest volume of barrels spilled compared to other companies. The top six companies contributing to the highest barrel spills across the country were SPDC (12,860.57), Nigerian Agip Oil Company (NAOC) (4,935.70), Heritage Energy Operational Limited (4,600.80), Aiteo (2,481.41), Warri Refining and Petrochemical Company (943.00), and ND Western (915.38).

In 2019, the reports of barrels spilled by companies increased compared to 2017 and 2018, reaching a total of 39,347.01 with 733 incidents. SPDC maintained its position with the highest volume spilled (9,502.89), closely followed by Heritage Energy Operational Services Limited (9,369.33), Aiteo (7,601.73), NAOC (4,653.88), Eroton Exploration & Production Limited (4,350.83), and ND Western (2,165.00). This rise in spillage could

be attributed to various factors, including a stronger commitment to regulatory compliance by certain companies, as suggested by the NOSDRA Oil Spill Monitor website.

In the year 2020, there was a decrease in the total barrels spilled by companies across the country, totaling 21,110.76 barrels with 440 incidents. SPDC maintained its position with the highest spills, reporting 11,207.62 barrels spilled, followed by Eroton E&P (4,770.88), NAOC (1,583.88), and ND Western (1,490.01). This decrease in spills compared to previous years, as per records from the NOSDRA Oil Spill Monitor, signifies a significant improvement.

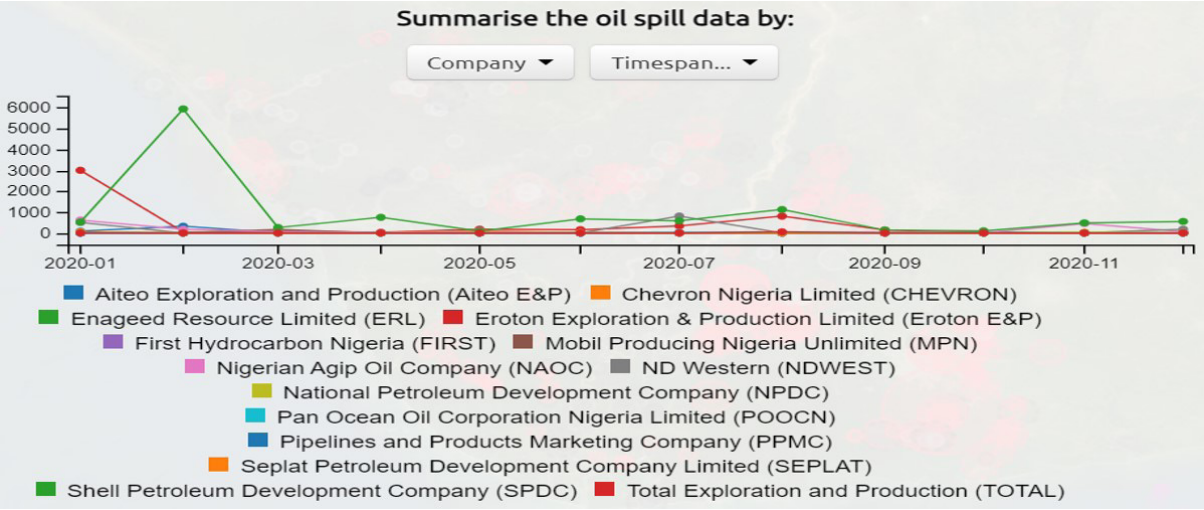

Figure 5: Barrels Oil Spill by Company and Months in 2020

NOSDRA Key Aspects of the Process of Reporting and Cleaning Up Oil Spills in Nigeria are Briefly Explained Here

- All oil spills must (by law) be closed-off/stopped by the oil company within 24 hours of being notified of an oil spill in their jurisdiction.
- A Joint Investigative Visit (JIV) must (by law) be carried out as soon as possible after a spill has been identified and containment measures taken. The Joint Investigative Visit is where the oil company representatives, community representatives, and appropriate government agencies visit the oil spill site to agree on the cause, impact, scale of spill etc. The resulting JIV document is signed by all parties present and forms the basis of any legal proceedings or compensation claims.
- Within 2 weeks of a spill being identified oil companies must (by law) submit information (FORM B - enshrined in Nigerian law) to the government regulator which outlines areas of impact, area covered by spill, quantities spilled, quantities recovered, cause of spill, containment, and cleanup measures etc.
- When further cleanup efforts by the oil companies or their contractors is deemed complete, the oil company should contact the government regulator with a report on their cleanup operations (FORM C - enshrined in Nigerian law).
- The oil company whose facilities have been compromised are always responsible for oil spill clean-up, regardless of the cause of an oil spill.

Issues Relating to Reporting and Cleaning Up Oil Spills in Nigeria.

Oil spills can result from breaks in ageing or poorly maintained infrastructure, accidents, vandalism, and other incidents. Over the past decade, several spills have also been caused by oil theft, commonly referred to as bunkering, where oil is stolen from pipelines for local or international markets. Additionally, there has been a rise in artisanal refining activities, where crude is refined in mangrove camps for local or other purposes, contributing to serious pollution due to lack of regulation. These issues include:

Corruption

Bunkering and oil theft are potentially lucrative businesses, and there are frequent allegations of high-level security, oil company and government corruption.

Security

accessing a spill site may be dangerous due to the presence of armed actors involved in bunkering or illegal refining.

Compliance

it may not be in the interest of a party responsible for an oil spill to report it, as they will be required to clean it up and provide compensation.

Community Obstacles

for a variety of reasons, local communities in affect areas

may not allow spill clean-up teams or regulators to access spill sites. This could be because of historical mistrust of companies and the authorities, or to hide community-level refining activities.

Environmental Guidelines and Standards for the Petroleum Industry in Nigeria

The establishment of DPR and NOSDRA, along with the document titled "Environmental Guidelines and Standards for the Petroleum Industry in Nigeria" (Department of Resources, 2002), delineate the responsibilities of oil companies. These entities expect oil companies to operate in a manner that prevents oil spills. However, should an oil spill occur within a company's operations, it is required to promptly report the incident to NOSDRA and undertake necessary cleanup actions. These obligations are outlined in Part III, Section 6, subsections 2 of the NOSDRA Act. According to subsection 2, an entity responsible for an oil spill must notify the Agency in writing, via fax or electronic mail, within 24 hours of the incident. Failure to report incurs a penalty of ₦2,000,000 for each day of non-compliance. Subsection 3 mandates a cleanup and remediation action plan within two weeks. Violation of these provisions entails a fine not exceeding ₦5,000,000 or imprisonment for up to 2 years, or both.

Communities, as significant stakeholders directly impacted by spills, are expected to report such incidents to NOSDRA. In practice, communities typically report spills to the relevant oil company. Community leaders are also anticipated to partake in site inspections following a spill. Alongside community representatives, joint inspection teams usually comprise members from NOSDRA, the oil company, and concerned environmental NGOs.

Common Type of Remote Sensing Devices Use for Oil Spill Detection

Multispectral imagery can be utilized for detecting and monitoring oil spills, as well as tracking oil migration and spread during floods. Oil spills have long been a significant challenge in the Niger Delta Region, resulting in environmental pollution with hydrocarbons and posing a critical global environmental issue. The use of remote sensing in identifying hydrocarbon spill locations and monitoring remediation sites dates back to the 1970s, initially involving the utilization of aerial photographs (Casciello *et al.*, 2011). Recent research has explored the effectiveness of ultraviolet (UV), thermal infrared, and microwave sensors in detecting oil contamination (Fingas & Brown, 1997; Brekke & Solberg, 2005). Advancements in sensor technology, data analysis, and communication in geospatial technology have led to the adoption of new methodologies. Satellite and airborne radar, LIDAR, hyperspectral, and multispectral sensors are among the remote sensing technologies used for monitoring oil pipelines or spills (Jha *et al.*, 2008). Remote sensing imagery has been successfully employed in identifying stress in plants due to hazardous liquid leakage, quantifying pollution and stress levels, and monitoring contaminated areas post-remediation (Van der Werff *et al.*, 2008). Using Landsat 7 Enhanced Thematic Mapper (ETM) images, researchers such as Zha *et al.* (2014) observed distinctive features of weathered oil suspended in the water column, characterized by bright contrast, and oil film floating on the sea surface, appearing dark. Environmental conditions, such as stress and dehydration in plants, can also be identified, both of which may pose risks (Carter, 1993).

CONCLUSION

Oil spillage remains a significant environmental and economic concern in Nigeria, particularly in the Niger Delta region, where the petroleum industry operates. Analysis of data from the NOSDRA Oil Spill Monitoring website reveals consistent patterns of oil spill occurrences, with certain companies consistently contributing to higher spill volumes. Despite regulatory frameworks and response mechanisms, challenges persist in effectively addressing and mitigating the impacts of oil spills. Remote sensing technology emerges as a valuable tool in oil spill monitoring efforts, offering timely and accurate data for identifying spill locations and assessing environmental damage. By leveraging data from the NOSDRA Oil Spill Monitoring website, stakeholders can gain insights into spill trends and prioritize intervention measures. However, proactive measures are needed to strengthen regulatory oversight, improve spill response capabilities, and promote transparency and accountability within the petroleum industry. The decrease in spillage observed in 2020 is encouraging, suggesting potential progress in spill prevention and response efforts. Nevertheless, sustained efforts are required to address the root causes of oil spills, including pipeline vandalism, equipment failure, and inadequate maintenance practices. Additionally, greater collaboration among government agencies, oil companies, and local communities is essential to effectively monitor and mitigate the impacts of oil spills in Nigeria. Only through concerted action and the adoption of innovative technologies can Nigeria achieve sustainable management of its oil resources and protect the environment for future generations.

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