GJEST

G- Journal of Environmental Science and Technology

A Critical Review of Oil Spill Data and Spill Management in the Niger Delta Region of Nigeria

Vremudia Onyeayana Wekpe, Malcolm Whitworth and Brian Baily

School of Environment, Geography and Geosciences (SEGG), Burnaby Building, University of Portsmouth, Portsmouth United Kingdom.

ABSTRACT

Readily available and reliable oil spill data is at the forefront of any meaningful attempt to manage the attendant negative effects of oil spills on the environment and livelihoods. The management of oil spills in the Niger Delta region (NDR) of Nigeria is an activity that brings together different stakeholders with the sole aim of mitigating and ameliorating the negative impacts of oil spills on the environment. However, it is evident that despite these concerted efforts in the attempts to manage the oil spill problem in the NDR, the problem persists. New cases of oil spill incidents are reported almost on a weekly basis with the attendant negative consequences accompanied by these spill incidents. Moreover, the vera city of these spill data is viewed with suspicion and apathy. This review is an attempt to appraise the state of oil spill data reporting in the Niger Delta and management efforts geared towards the reduction of oil spill incidents in the region. Data on reported oil spill incidents were reviewed and analysed. Evidence from the review suggests that effective management of the oil spill problem is hampered by excessive red tapism that exists in the management framework of spills in the region. The review concludes that significant investment in oil infrastructure will provide lasting solutions to the problem and recommends the adoption of powerful modelling software to monitor oil spills as well as the use of geospatial techniques, community engagement and proper environmental surveys of the region.

Key words: Environmental Management; Spill Data Reliability; Proportional Environmental Reporting; OSIR

1) INTRODUCTION

Oil spills are hazardous to any environment, often having negative environmental, economic and social impacts when it occurs [1, 2, 3, 4]. These negative impacts may amplify into disaster situations if not adequately managed and properly prepared for in the form of contingency planning and proactive pragmatic responses [2, 5, 6]. These responses must consider the peculiar environmental and social consequences on the area or environment being planned for based on adequate and reliable oil spill data sets [4]. The most widely discussed environmental pollution problem in the Niger Delta region that has made it infamous globally is the problem of pervasive oil spills in both the marine and terrestrial environments [2, 6, 7, 8]. The inability to manage this problem successfully over the years may not be unconnected with the poor and unreliable state of oil spill data reported for the region [9, 10].

Reliable and readily available oil spill data and oil spill reporting efforts play a vital role in facilitating positive results as well as achieving meaningful progress in the planning and management actions undertaken in tackling oil spill problems [10]. This assertion by Watts and Zalik [10], becomes rather ominous when juxtaposed against the

backdrop of the environmental and social peculiarity of the Niger Delta Region of Nigeria (NDRN) [1, 6, 7]. The problem of unreliable oil spill data has been inappropriately underestimated as it relates to its use in managing and planning for the control of the pervasive oil spill problem in the Niger Delta region of Nigeria [9, 10].

In Nigeria and the Niger Delta (ND), the availability and state of reliable oil spill data can at best be described as questionable or unreliable [10]. Attempts to gather reliable oil spill data for different purposes have significant problems as a result of glaring discrepancies in spill data records reported by various regulatory institutions, communities' non-governmental organizations (NGOs) and corporate sources in the country [10, 11, 12, 13]. Widespread accusations and counter accusations fly around that oil spill incidents in the Niger Delta could be over reported or under reported depending on the specific bias of people involved in the reporting efforts. The oil producing communities or communities that have some form of oil facility or installation would always assert that the spill incidents are under reported, while the multinational oil companies would argue that the values

* Corresponding Author: **Vremudia Onyeayana Wekpe**
Email address: vremudia.wekpe@port.ac.uk

reported by the communities and NGOs are significantly over bloated [12, 13, 14]. This lack of trust in the spill data reported has continually bred mistrust amongst stakeholders in oil spill control and management efforts, thus effectively sabotaging meaningful progress as valuable time is spent first trying to validate and harmonize the available oil spill information [10]. This mistrust becomes even more compounded when juxtaposed against the fact that the people of the Niger Delta are naturally suspicious of outsiders [15]. This suspicion could have arisen due to years of deliberate neglect and marginalization of the people and environment of the Niger Delta from the colonial times, through the period of the Nigerian civil war and present times [16].

Over the years, the occurrence and reportage of oil spill incidents in the Niger Delta (ND) has been fraught with inconsistencies and has been treated with consistent mistrust and serious apathy by interested parties ranging from the oil companies, the regulatory agencies, communities, media outlets, the government and its agencies and non-governmental organizations (NGOs) [1, 12, 13, 14]. This mistrust and apathy are hinged on the factual or nonfactual reporting of oil spill incidents in the ND and the associated or non-associated consequences of the timely, truthful and unbiased presentation of the elements of an oil spill event. It has been reported that between 1976 and 2001 there were nearly 7,000 incidents involving oil spills and most of the oil spilled was never recovered from the environment [11]. The occurrence, number and frequency of oil spill incidents in the ND are regarded to be among the highest in the world as highlighted [6].

Review Scope

This paper is a review article that focuses primarily on the analysis of available literature and data on oil spill and oil spill management. Oil spill data from various sources was evaluated with the goal of identifying where discrepancies are in the available data. An attempt will be made to identify the sources of these discrepancies with a view to providing a more harmonized approach to recording oil spill data. The rationale behind this being that more accurate spill data reportage will promote a more efficient management of the oil spill problem in the NDR. The issues that form the fulcrum of the review are organized accordingly into:

- Overview of the Niger Delta Region
- The problem of oil spill and the causes of oil spill in the Niger Delta
- Environmental legislation and management of oil spills in Nigeria
- Management options for oil spill control in the Niger Delta

2) OVERVIEW OF THE NIGER DELTA REGION

An attempt to define the Niger Delta region often times generates controversy especially in political circles and the allocation of developmental resources. Yet it has been defined and described severally by experts and non-experts alike. The term "Niger Delta" has been used from various perspectives by different people depending on

their biases and points of departure as well as affiliations (geology, geography, sociology, geomorphology, ecology, socioeconomic development and political governance) [6]. In terms of general and combined definitions, the Niger Delta can be defined or described geologically (a definition or description of the Niger Delta as it was) as has been done [17, 18]. The Niger Delta can also be described geomorphologically (a description of the Niger as it is) [19, 20]. The Niger Delta can also be described or defined geopolitically (a description of the Niger Delta as we are) [6, 16, 21]. The NDR has been described as mostly a flat swampy basin, crisscrossed by an intricate and dense network of rivers, creeks and streams. Its topography, geology and soil properties, hydrodynamics and heavy rainfalls make the region highly vulnerable to incidences of annual flooding and erosion; throw in a mix of people of who are deeply suspicious of outsiders and any attempt to research the region becomes quite challenging [6]. This general suspicion with which the people regard outsiders may not be unconnected with the disdain and deceit with which the people have been treated and dealt with in the last five decades in terms of resource extraction and infrastructural development [1, 6, 15].

The NDR is reported to have about 13,329 settlements with only about 98 classified as urban settlements and the others as dispersed and isolated rural communities whom are often times cut off from the most basic amenities and infrastructure. The NDR also hosts over 800 oil field communities with over 900 active oil wells and thousands of other oil exploitation infrastructures [22]. In terms of socio-economic development, the region could be described as being a rich region with poor people [1, 16, 21,]. It is blessed with abundant crude oil and natural gas, which is the main stay of Nigeria's economy. Apart from crude oil and natural gas, the mangroves offer a lot of biological resources on which the rural livelihoods depend on Mmom and Arokoyu [20].

The importance of the implementation of tools to prevent and mitigate the potential impact of oil spills in the natural environment cannot be overemphasized as it is an issue of interest not only for oil producing companies, but also for the government, local communities and civil societies. The implementation of these tools will to a large extent mitigate possible damages to the natural environment and the human use resources extracted from the environment [23]. Added to these, the human health problems, impaired aesthetics and associated general ecological imbalance makes the need to proactively manage the environment of the NDR very imperative [6]. The Niger Delta as a young delta undergoes continuous deposition and dewatering of sediment, as such accelerated coastal erosion and river flooding are evident in many parts of the low lying plain; this low-lying nature of the Niger Delta makes it vulnerable to eutstacy accentuated by resource extraction and natural subsidence [24]. When this is juxtaposed against pervasive and persistent spill events, the picture painted becomes quite bleak.

According to the Niger Delta Development Commission, (NDDC, 2006), an estimated 88% of rural dwellers in the NDR live below the poverty line. These statistics becomes very alarming when viewed against the backdrop of the

people of the Niger Delta coastal areas (which are predominantly rural) being heavily dependent on the meager sources of livelihood which comes from mostly fishing and agricultural activities. This implies that the people of the region, especially those dependent on resources that are susceptible to oil spill perturbations are socially, and economically vulnerable [4, 16, 25]. Oyedepo and Adeofun [26], posit that since environmental/ ecological degradation from oil spill results in the gradual erosion of biodiversity pools and species, which incidentally forms the basis for the survival of the human species, prevention of this kind of disaster through rapid and precise response action is not negotiable. Meanwhile, comprehensive information on the sensitivity levels of each category of a susceptible environment is an important requirement for effective oil spill disaster management. Regrettably, robust and reliable oil spill data that would support management schemes such as Environmental Sensitivity Index (ESI) documents are not readily available [10]. This further imposes limitations to the development of appropriate and robust oil spill contingency plans for the study area.

3) THE PROBLEM OF OIL SPILL AND THE CAUSES IN THE NIGER DELTA

3.1. The oil spill problem in the Niger Delta Region

The problem of oil spill is a very significant topic for discussion as the physical environment of the ND has been severely degraded over the years by pervasive and uncontrolled oil spills [7, 8, 11, 12, 13, 27]. Oil spills have been recognized as a global environmental problem with devastating negative effects at both the local and regional scales [28]. A deep and in-depth evaluation of the problem of oil spill in the ND would potentially highlight negative outcomes with salient environmental and social consequences. Conceivably, the resulting problems and issues can be adequately and proactively managed with effective and efficient programs designed to suite the peculiarities of any given environment such as the Niger Delta region of Nigeria [5].

Over the years several hundreds of thousands of barrels of crude oil has been released into the natural environment of the ND comprising of the land and water through leakages in damaged and corroded oil [8, 29]. The losses of oil to the environment are as a result of poor and irregular maintenance of the pipelines and crude oil storage facilities. Badejo and Nwilo [30], contend that by international standards, oil pipelines need to be replaced after 15 to 20 years of use, but in the Nigeria and the Niger Delta, most of the pipelines are over 25 years old thereby making these pipelines susceptible and vulnerable to corrosion and eventual leakage.

The delicate marine and coastal ecosystems in the Niger Delta have been severely damaged by oil activities in the region which in turn negatively impacts on the socio-economic livelihood sources and daily maintenance of coastal dwellers in the ND [25, 27]. In X-raying the magnitude of work yet to be done on the problem of pervasive oil pollution and environmental degradation associated with both onshore and offshore petroleum exploration, exploitation and production operations in the

Niger Delta, as well as the need to provide proactive, timely, effective and efficient solutions to the persistent problem, Ite et al., [9], concluded that the problem of managing oil pollution and environmental degradation in the ND has not been properly addressed for over five decades of oil exploration and exploitation in Nigeria. This line of argument is in tandem with the conclusions of other researchers who agree that the pervasive cases and incidences of oil spills recorded in the ND must be addressed to ensure the continued existence and survival of the environment and the people of the Niger Delta [5, 7, 31]. The Niger delta is beset by a myriad of problems as identified by Boateng [32]. These problems include: flooding, siltation, erosion and submergence of developed areas as well as pervasive environmental degradation occasioned by anthropogenic elements and activities such as oil exploration and exploitation activities which can result in oil spills [33, 34]. Oil spills have been identified as one of the most significant and frequently occurring environmental hazards in the Niger Delta [6, 8]. Residents of the region depend directly on the natural environment for their food and livelihoods; therefore, they are in constant contact and suffer direct exposure to oil pollutants in their environment [32]. The waters off the coast of West Africa have been identified as one of the richest in terms of the fisheries resources that can be found in the world, yet the inhabitants of these regions remain some of the poorest and vulnerable populations [25]. These fisheries resources include different species of molluscs, finfish and crustaceans [35].

Kadafa [36], identified the Niger Delta as one of the ten most important wetland and marine ecosystems in the world. This wetland is highly productive in terms of supplying needed water and nutrients to sustain the biological productivity of the region [35, 36, 37]. The Nigerian oil industry also located within the region has contributed significantly to the economic growth and development of the Nigeria. However, despite the importance of the Niger Delta region (NDR), unsustainable oil exploration, exploitation and production practices and activities have rendered the NDR one of the five most significantly petroleum degraded ecosystems in the world [36, 37]. The need for contingency planning built on robust oil spill data therefore becomes rather imperative for oil spills response and management to provide a safe, systematic and integrated response to oil pollution incidents that may occur in a sensitive environment like the coastal areas of the Niger Delta and the associated human use resources that are found in these areas [39]. Nigeria is one of the largest producers of oil in the world and the largest producer in African with an average production capacity of 2.7 million barrels per day (bbl/d) in 2006 [40]. However, by July 2019, the production was 2.11 million bbl/d [41]. Data on oils spills in Nigeria obtained from the Nigerian oil spill monitor shows that of the 1317 spill incidents reported between March 2018 and March 2020, a significant number (1,148) of those cases occurred in the Niger Delta region accounting for 87.16% of reported and recorded cases. The remaining 169 cases distributed across the rest of the 32 states of Nigeria and

the Federal Capital Territory (FCT) Abuja accounted for 12.83% of reported and recorded spill incidents (Figure 1).
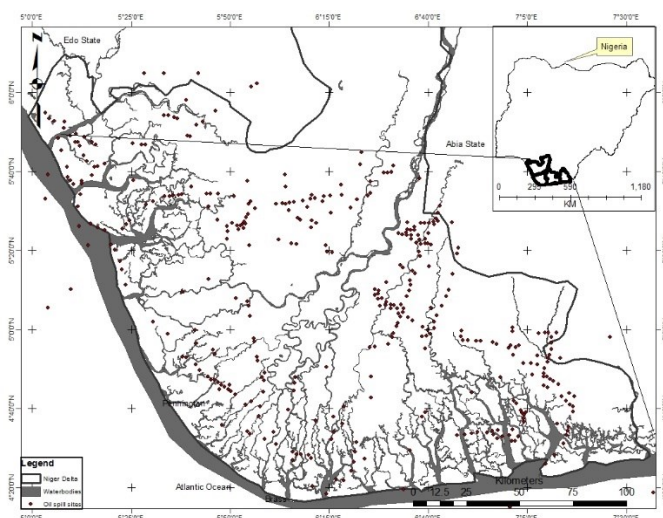
Figure.1: Oil spill incidents in the Niger Delta (Spill data obtained from NOSDRA).

3.2 Perspective on crude oil and crude oil production in the Niger Delta

Crude oil is a very important commodity that supports and promotes the economic development of any country [1, 42, 43]. This assertion is certainly true in the case of Nigeria whose rapid economic growth and wealth is tied to the liquid gold found within its subterranean cavities in the NDR [44]. Crude oil was first discovered in the NDR in the small sleepy village of Oloibiri in the old Rivers State (now Bayelsa State) in 1956 by Shell British Petroleum (now Royal Dutch Shell) while commercial exploitation and production activities began in 1958. Today, there are about 606 oil fields in the Niger Delta, of which 360 are on-shore and 246 offshore [45, 46]. These oil fields are connected to each other by an extensive network of over 3000 kilometers of pipelines zigzagging across the regions subterranean cavities and waterways linking some 275 flow stations to various export terminals [45, 7]. Nigeria is reputed to be one of the largest producers of oil in the world and the largest producer in Africa with an average production capacity of 2.7 million barrels per day (bbl/d) in 2006 [40].

Before the discovery of oil in the 1950s, agriculture was the mainstay of the Nigerian economy, with agricultural produce exported to the more industrialized regions of the world. However, by 1971 there had been a shift from agriculture to petroleum production (UNEP, 2011). This singular reason defines why the Niger Delta region is very important to the welfare and stability of the Nigerian economy, as it harbors within it subterranean reservoirs oil wealth. However, the region also hosts the economic hub of Nigeria, with the region accounting for more than 90% of the nation's foreign exchange earnings [7, 40, 47].

The NDR has experienced continuous incidents of oil spills over the last 60 years with devastating and far reaching consequences on both the environment and public health of the people of the region [2, 6]. Since the discovery of oil and its subsequent exploration and exploitation, oil has been vital to the development and advancement of contemporary societies and economies due to its wide-ranging use in energy, transport and manufacturing. It is estimated that worldwide, for a period covering the last 35 years; energy use has doubled, contributing to a 7-fold increase in gross domestic product (GDP) in that time. During this period, crude oil has dominated world energy supply, constituting 34 per cent of total primary energy supply in 2017 [3]. The implication of this assertion by Byrne [3], is that the foundations and maintenance of modern economies are significantly dependent on the continued production of crude oil (Table 1). Even as an attempt is continuously made by the advanced economies to shift their energy uses away from fossil fuels, the third world economies of the world are far behind in this regard and will continuously depend on the energy sources supplied by fossil fuels for the foreseeable future to meet up with their energy demands. This can be seen in the continuous prospecting for new and more productive offshore and offshore oil blocks (Table 1.1). The implication of this assertion is that crude oil exploitation and production will continue to remain a major component of the global energy and industrial mix for the foreseeable future. The information presented in table 1.1 is that more exploration for crude oil is ongoing and that comes with the attendant issues of spills and its associated negative consequences.

Table 1: Planned Oil Exploration Projects in Nigeria

Project Name	Operator	Type	Location	Production plateau (thousand b/p)	Estimated state date
Qua Ibo	NNPC	Crude oil	Onshore	90	2021
Zabazaba Etan	ENI	Crude oil	Offshore deepwater		
Bonga Southwest Aparo	Shell	Crude oil	Offshore deepwater	150	2022
Preowei	Total	Crude oil	Offshore deepwater	50	2023
Owowo	ExxonMobil	Crude oil	Offshore deepwater	160	2024

Source: U.S. Energy Information Administration (2020)

3.3 Causes of oil spill in the Niger Delta

An oil spill incident which is the inadvertent release or discharge of petroleum hydrocarbon products into the marine or terrestrial ecosystem [2, 49]; and which has the attendant potential of causing severe and sometimes long-lasting damage to the natural environment. Griggs, [50], and Upton [51], agree that major oils spills in the marine environment have mostly been caused by accidents involving transportation activities through vessels and coastal oil production facilities while terrestrial spill incidents are often caused by a combination of sources. Oil spillage can arise from two broad categories; natural and manmade sources with a further third category being mysterious causes or sources [29, 45, 52]. The spills caused by natural events describe spills that come as a result of natural or environmental perturbations such as those that occur due to natural disasters, shift of tectonic plates, or the occurrence of and flow of crude oil on the earth surface as occurs in Ondo State in the Niger Delta region of Nigeria [29, 53]. The challenges presented by the occurrence of oil spills often times present a unique and yet dynamic set of societal and environmental dilemma. Data from various studies clearly indicate that human error accounts for about 80% of the major oil spills in the world [54, 55]. Badejo and Nwilo [30], contend that 50% of oil spills emanate from weak pipelines due to corrosion, while 28% is attributed to sabotage. An increasingly amount of spill is being attributed to activities of artisanal refineries with significant losses of crude to the environment [1, 56]. 21% of oil spill is arises from oil production operations and 1% of oil spills originate from operational failures such as engineering drills, inability to effectively control oil wells, failure of machines, and inadequate care in loading and unloading oil vessels.

The majority of oil spill incidents that occur in Nigeria occur in the Niger Delta. Data obtained and analysed from the National Oil Spill Detection and Response Agency (NOSDRA) shows that of the 1317 spill incidents reported between March 2018 and March 2020, a significant 1,148 of those cases occurred in the Niger Delta region accounting for 87.16% of reported and record cases. The remaining 169 cases distributed across the rest of the 32 states of Nigeria and the FCT accounted for 12.83% of reported and recorded cases.

As an ever-increasing amounts of oil products are being released into the biosphere; non-conservative estimates of the amount of oil spill in oceans have been put at values as high as 1 to 10 million metric tonness per year, with the most likely rates being close to the middle of this range [57]. The occurrence of a majority of the oil spills are due to the release of small but continuous quantities of oil from tanker operations, industrial discharge and on-shore and offshore oil facilities as well as poor waste disposal practices [57]. The problem of oil spill has been identified as a very serious problem which the people and the environment in the Niger Delta have to continually contend with [11] Wekpe [7], described the problem of environmental pollution and degradation in the Niger Delta as an ever-present ailment which the people and the environment of the Niger Delta have come to associate with as the new normal even at the detriment of human

and environmental integrity; and the continued survival of the physical environment as well as the litany of elements that depend on the products of the environment for nourishment, provision and sustenance.

3.4 Oil Spill Data Problems in the Niger Delta

The challenges posed by poor and unreliable oil spill data in the Niger Delta Region often emanates from the inconsistencies present in the reporting of spill events in the region [10]. Arguments usually arise in various public fora where the issues of oil spill and measurement are discussed. The usual bone of contention in these arguments revolves around the authenticity and reliability of spills data reported and recorded. This lack of trust in the data reported is not unconnected with the often biased and untimely reported spill incidents [10].
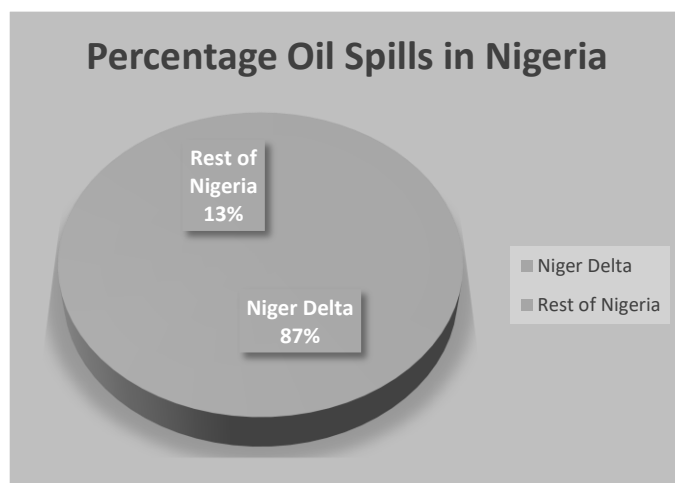

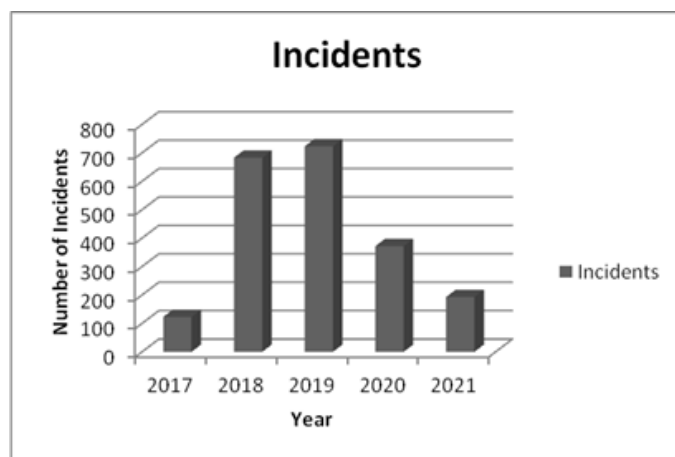**Figure 2**: Percentage oil spill occurrences in Nigeria.

Figure 3: Annual oil spill incidents in Nigeria (in volume) (Source: NOSDRA)

Lawal and Oyegun [5], posit that in Nigeria, it is quite obvious that even with the best laid plans; the management of disasters requires an iterative, repetitive and continuous evolution of techniques, actions and measures. They further reiterate that it is only a clear understanding of the impacts of oil spills that will prevent future and possibly worse outcomes because of the lack of adequate data and information to guide actions and deployment of resources for preparedness and response. Kankara et al., [58] contend that the use of any oil spill

response method such as the use of equipment and recovery tools like booms and skimmers to recover floating oil and dispersants that enhance natural dispersion requires a careful understanding of the physical, biological and social settings of the area under inquiry, threat or investigation. In the Niger Delta, this is not the case as the plethora of studies on the Niger Delta have not been harmonized to provide a single working document that will address the peculiar challenges of the Niger Delta environment [5, 9, 40, 59].

In Nigeria, the guidelines specified and required for reporting an oil spill incident is spelt out in the environmental guidelines for the oil industry in Nigeria (EGASPIN) issued by the Nigerian Department of Petroleum Resources (DPR) and the guidelines defined by NOSDRA for its joint investigative visit (JIV) as well as the Nigerian Federal Ministry of Environment and the concerned state ministries of environment. Although this appears to be a standard guide for operation the red tape involved in contacting and conducting a JIV ultimately diminishes the reliability and integrity of the measurements obtained, as a significant quantity of the spill would have been lost to the environment through leaching, erosion or evaporation.

In order to enhance the accountability and reliability of oil spill data reports and improve on its mandate, the NOSDRA's Oil Spill Monitor (OSM) was introduced in 2014. The introduction of the OSM was at the time seen as a critical and timely addition to the existing structure of NOSDRA to statutorily anticipate and mitigate the potential catastrophic impact of oil pollution on present and future generations in the Niger Delta [60]; but almost a decade down the line, the pervasive nature of spills in the NDR continue [10].

3.5 Anomalies in oil spill data
Inconsistencies in data reported for oil spill incidents have been at the fore front of lack of trust in data reported for Nigeria and the Niger Delta (Figure 3). Elekwachi et al., [13], reports that there have been about 1,930 reported oil spill incidents between 2013 and 2014, with the most publicized in recent times being the Bonga oil field blowout of 2011. The Bonga oil spill introduced over 40,000 barrels of crude oil into the Atlantic Ocean in 2011 and the impacts were felt in more than 20 riverine communities across Akwa Ibom, Bayelsa and Delta States [12, 14]. However independent reports estimated the amount of oil spilled at approximately 58,000 barrels which resulted in the recommendation by the Federal House of Representatives and National Oil Spills Detection and Response Agency in December 2014 that of $3.96 billion for about 168,000 victims of the incident should be paid as compensation [14].

### 3.6 Causes of anomalies in reported oil spill data in the Niger Delta
A number of factors can account for anomalies in recorded data ranging from human error (such as inaccurate calibration), equipment failure, spill measurement or monitoring methods to time induced natural decay. The very nature of crude oil determines the rate of degradation or break down [3]. As such, natural induced actions such as weathering, evaporation, oxidation and biodegradation can reduce the severity of a spill event in terms of the recoverable and measurable quantity of spill [61].

When the natural actions that degrade crude oil are combined with time needed to organise and embark on a joint investigative visit (JIV), the true scale and impact of a spill event may have been lost due to losses to natural attenuation (figure 6). The earliest time most JIVs take place is usually after two days of the spill occurring while other JIVs can take up to two weeks after the spill to be embarked upon. This red tapism and slow response rate effectively jeopardizes the quality of information generated

Table 2: Oil spill volume estimation methods

S/N	Media	Estimation methods	Estimation Type	Case studies	Application	References
1	Water	SAR	Off site (Remote Sensing)	Milford Haven Wales (1996)	Used to estimate size and extent of spill, direction and magnitude of oil movement	Byrne [3]
3	Land/water	Pressure device guage or pressure valve	In-situ and off site	BP Gulf of Mexico spill	Measures the volume of oil passing through a point	Mohaghegh [62]
4	Land/water	Manual measurement	In-situ	BP Gulf of Mexico spill	Estimates the amount of recovered oil from land or water	
5	Land/water	Aerial surveillance	In-situ observation and ex-situ estimation	Milford Haven	Estimates quantity of spill from drones or pictures and estimates taken from low flying aircrafts	Byrne [3]
6	Water	Numerical modelling	Mathematical models	BP Gulf of Mexico spill	Mathematical models are applied to simulate the behavior of spills and their movement and fate in water.	Lehr et al., [61]; Elizaryev et al., [63]; Nelson and Grubesic [64].

afterwards. This ultimately serves to create discrepancies in the data reported by the oil companies, NOSDRA and other interested parties (figure 4 and 6).
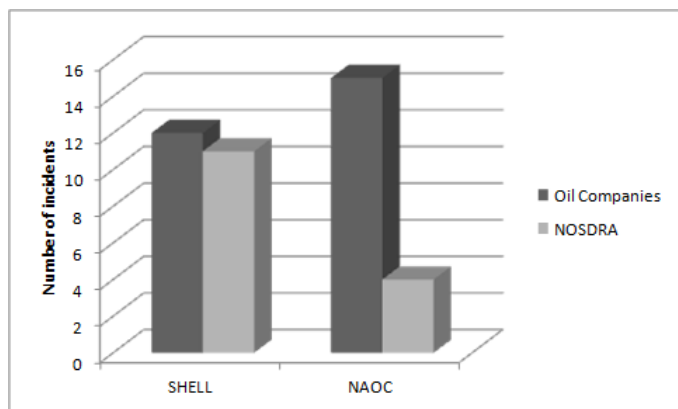

Figure 4: Contrasting oil spill incidents reported by oil companies and NOSDRA (Source, SHELL, NAOC and NOSDRA).
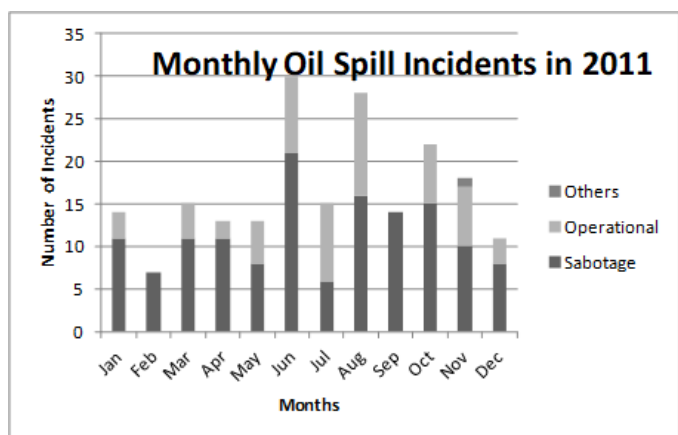
Figure 5: Monthly Oil Spill Incidents in 2011 (Source: SHELL)

The methods adopted in estimating the amount of oil spill also contributes to the anomalies observed in reported and recorded data for Nigeria and the Niger Delta Region. The location of a spill (on water and or on land) helps to determine the most suitable method for the estimation of spill volume (table 2). The various oil producing companies operating in the Niger Delta adopt an independent method

for oil spill volume estimation specific to its individual operations while NOSDRA usually relies on the outcome of a JIV to update its oil spill incidents record book. This scenario creates a situation where a variation in the reported data becomes quite rampant and unavoidable.
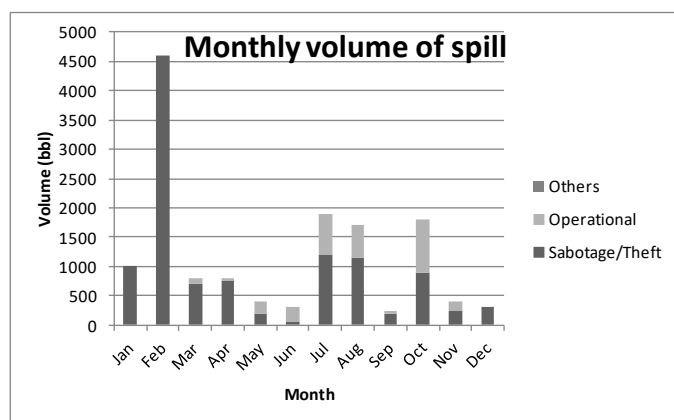
Figure 7: Monthly Oil Spill (in volume) Incidents in 2011 (Source: SHELL Spill Data)

The Shell Petroleum Development Company (SPDC) used interchangeably as SHELL, the owners of the Bonga oil field in their reports for oil spill incidents for December 2011 reported 300bbl (figure 5). These discrepancies in the quantity of spill data reported by different organizations brings into acute view, the focus of this review paper. The cause of the spill for December 2011 incident for December 2011 was reported by Amnesty International as operational failure, while SPDC stated that the cause of the spill for the period under review was as a result of sabotage. Anomalies and discrepancies such as these pose more questions than answers as it relates to the integrity and veracity of spill data records reported in the NDR.

A discrepancy in the data for December 2011 is in the volume of spills reported by various organizations. NOSDRA reported about 40,000bbl as what was spilled in the incident [14], while Amnesty International [12], reported that the spill was above 56,000bbl, however, SPDC in its online oil spill data archive reports that the spill event which she attributed to sabotage was about 300bbl (figure 6 and figure 7). These types of significant discrepancies tend to contribute in eroding the already
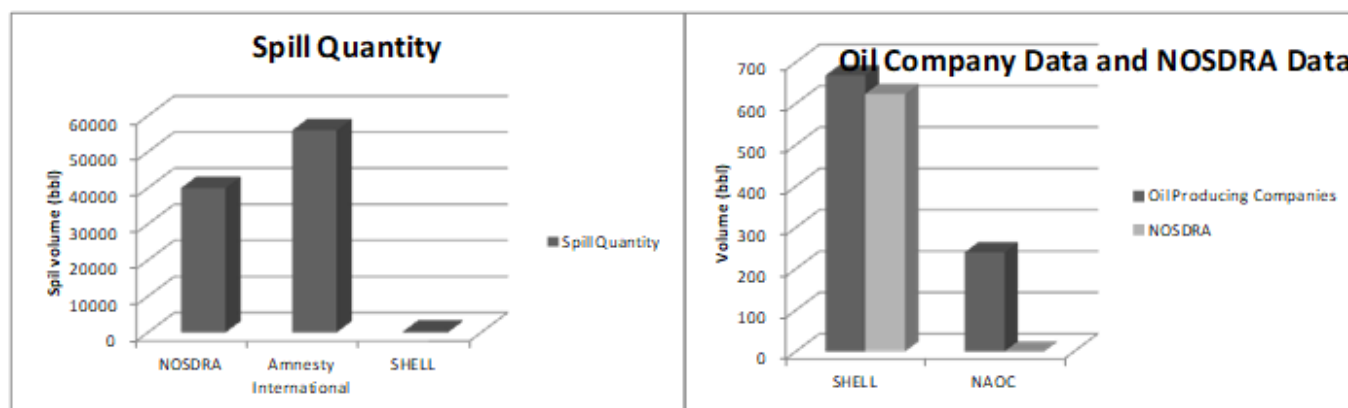
Figure 6: Contrasting oil spill volume reported by different bodies (Source, SHELL, NAOC, Amnesty International and NOSDRA).

fragile confidence in the crude oil production and management milieu.

4) MANAGEMENT OF OIL SPILL IN NIGERIA AND THE NIGER DELTA

Oil spill management all over the world is a task that is dealt with using a multi-agency approach which is normally coordinated through a National agency [58]. In Nigeria, the management of oil spill related issues cuts across different agencies of government from the Federal to the State levels. The management and control of oil spill incidents often follow a reactionary response to an event rather than taking a preventive and in a worst-case scenario a proactive preparation for a potential oil spill pollution event [7]. In Nigeria, the multi-agency cooperation of oil spills management is coordinated by NOSDRA. They are often the coordinators in the event of an oil spill and they lead the investigation when an oil spill occurs in Nigeria. The other agencies that participate in the management process include the Federal and State Ministries of Environment, the Department of Petroleum Resources (DPR), the Company on whose facility or operating area the spill occurred, the Police and representatives of the community on whose land (soil and water) the spill occurred. In the event of a spill, the concerned government agencies are mandated by law to manage and remedy the outcome of the spill event as well as recommend appropriate compensation to aggrieved parties; where there arises a failure to reach a consensus, aggrieved parties and organisations can resort to the law courts [65].

The DPR, which was formed as a unit inside the Federal Ministry of Petroleum Resources is mandated to develop and enforce general regulations for the petroleum sector in Nigeria [2, 40]. The general regulations and responsibilities of the DPR include the development of environmental standards and the management of oil spill cleanup incidents [65]. Between 1992 and 2002, the DPR developed and issued the non-binding Environmental Guidelines and Standards for the Petroleum Industry in Nigeria (EGASPIN) which essentially forms the foundation for most environmental regulations in the petroleum industry in Nigeria [65, 66, 67]. The DPR is significantly empowered by law to enforce the regulations and can arrest defaulters, summon oil companies, suspend the operating license of erring oil companies. A potential weakness of the DPR lies in the leeway given to the Director General of the agency who is empowered to act on discretionary basis. The extent to which he decides to exercises these powers is often up for debate [67]. NOSDRA on the other hand is specifically mandated to prepare for, detect and speedily respond to all incidences of oil spill in Nigeria as well as form and coordinate responses, determine, recommend and impose fines on oil companies that fail spills within a 24-hour window. The agency is also responsible for oil spill cleanup operations, remediation of contaminated sites and act as a mediator between the communities whose lands and waters are contaminated and the companies whose facilities triggered the spill [65]. The oil spills that over the years have originated from the operations of the upstream petroleum operators in Nigeria have remained largely un-remedied due to weak enforcement of environmental laws and regulations [68].

4.1. Oil Spill Detection and Monitoring in the Niger Delta

Oil spill monitoring in the Niger Delta Region of Nigeria can be best described as touch and go [7]. This describes a situation where the monitoring of spills in the region is left to chance. Since the issues of oil spill monitoring began in the United States of America, various methods have been devised to monitor oil spills as well as monitor and report the observed attendant impacts of these spill events on the natural environment [69, 70]. In Nigeria, real attempts to monitor the environment began after the 1987 dumping of toxic waste in the Niger Delta. Generally, oil spill incidents can be monitored using two broad approaches; in-situ monitoring and remote monitoring. These two approaches are complimentary rather than exclusive in their use as data from both approaches are mutually reinforcing. These mutually reinforcing advantages can improve the general results of monitoring and therefore improve the confidence placed on monitoring activities [2, 5, 26, 39, 40, 71, 72, 73, 74].

Terrestrial oil pollution has been identified as a major culprit in the rampant ecological destruction in the NDR which has led to significant damage to the mangrove ecosystem of the region and available arable cropland [2]. To further forestall the continued destruction of the delicate balance of the environment of the Niger Delta Region, a combination of in-situ measurements and monitoring is required to halt or at the least limit the damages that have been experienced and are being experienced. The use of remote sensing data and satellite imagery for oil spill monitoring has been going on for a while and with the advances in Space Technology, these tools have continually improved with near infinite capabilities and applications. Remote sensing and GIS capabilities have been deployed to monitor, measure and model oil spills' drift over time in the United States [69, 70, 75].

The use of remote sensing technology to detect and monitor both terrestrial and marine oil spill incidents over in Nigeria and the Niger Delta has been demonstrated by several authors [2, 71, 73]. The use of satellites in monitoring oil spills has an inherent advantage in that the spill can be localized and monitored and increases the chances of identifying the culprit of the spill. The added advantage of being able to remotely detect spills saves time and improves the response and containment efforts. The importance of the capability to remotely monitor and detect spills cannot be overstated because of the inherent and grave danger posed to the environment by oil spills. The use of satellite systems in monitoring oil spills can act as a beneficial monitoring tool if appropriately deployed [76]. Remote sensing platforms allow for early detection of oil slicks, provide areal extent of the spill, and also help model and predict the movement of the slick and possibly the nature of the oil. This information will be valuable in aiding clean-up operations, and will not only help save

wildlife and maintain the balance of the local ecosystem, but will also provide damage assessment [52, 75, 76].

The data extracted from remote sensing platforms can then be presented to show the distribution of oil spill data and sites as well as related data products using web-based Geographical Information Systems (web-based GIS); of great importance is the capability to generate automated thematic maps of the oil spill scene along with their web-based distribution is increasingly important [76]. Satellite remote sensing has been shown by various researchers to be an effective mechanism and method to detect and monitor vegetation health and status in polluted areas [73]. Thus, the vegetation health status of the Niger Delta Region can serve as a viable, fast and trustworthy technique for monitoring oil spill incidents by constantly monitoring the vegetation health of the region. This has been amply demonstrated [2], who applied remote sensing techniques to map and monitor terrestrial oil spill impact using machine learning and Landsat 8 OLI imagery. The numerical modelling approach is proving to be very important as an emergent tool in oil spill management as it possesses the capacity to simulate varying scenarios and address the issue of oil dispersion in the case of a spill. Computer models provide a valuable decision support capability that will aid in making decisions and predictions about the general trajectory and fate of spilled oil and to estimate the likely sensitive resources threatened [58, 61, 62, 64, 77, 78].

5) APPROACHES FOR RELIABLE INFORMATION FOR OIL SPILL MANAGEMENT IN THE NIGER DELTA REGION OF NIGERIA.

This study contends that for meaningful progress to be made in improving the reliability of oil spill data in the Niger Delta Region, the following recommendations should be pursued.

5.1. Adoption of powerful software

The adoption of Google Earth Engine capabilities; The Google Earth Engine Platform (GEEP) as an emerging platform for accessing satellite imagery needs to be explored as a tool that is relatively cheap to provide areal detection and monitoring of oil spill incidents in the NDR. The GEEP is as an online web portal which has the capacity to provide global time series satellite imagery and vector data [79, 80, 81]. The GEEP is a viable tool for quickly utilizing archive satellite data as it simplifies pre-processing steps, allowing focus on the translation of the core temporal segmentation algorithm [80]. The GEEP is a cloud-based geoprocessing platform designed to provide computational free and unlimited access to vast geospatial datasets. GEEP has been identified as a veritable and attractive tool because it offers free access to an almost limitless archive of satellite data, as well as its growing user based encouraged by the straightforward management of time series stacks, and ease of parallel processing to speed computation [80, 81]. To complement the results and outputs from the GEEP, the use of environmental sensitivity index maps is also suggested. Environmental sensitivity index (ESI) maps are a compilation of information about environmental sensitivity, biological resources, and human use resources

in mostly coastal environments. This information is used in planning to create cleanup strategies before an accident occurs so that authorities are prepared to act in the event of such a spill. ESI Mapping has a solid advantage in oil spill contingency mapping and management in that it has an inherent ability to rapidly visually and highlight, sensitive areas deserving immediate attention and protection using geospatial techniques and ancillary data [44, 51, 82].

The analysis of mapped environmental components that may be susceptible from oil pollution is a very salient topic for discussion in developing, coordinating and providing support programs for timely and adequate response strategies and priorities for the effective and efficient protection, conservation and management of vulnerable coastal and human resources [2, 23, 72]. In Nigeria and like most developing countries, resources are scarce and therefore need to be effectively and efficiently deployed for the optimisation of benefits. The deployment of well-developed ESI maps will aid in the allocation of scarce resources where they are most needed.

5.2. Community engagement and awareness

Initiatives to improve community engagement and education are also advocated as a prerequisite for sustaining any gains that can be achieved from the deployment of technology and ESIs. The role of continues engagement with the local communities of the NDR cannot be overemphasized as the people are the ones who are mostly impacted by the negative impacts of the spills. The engagement must be such that educates the people on the inherent dangers in attempting to tamper with the oil pipelines as an alternative and quick access to a livelihood. These engagements must be structured around programmes to reduce poverty among the local people as poverty is at the base of the issues of tampering with the oil pipelines. This can come in the form of coastal zone renewal and regeneration programmes.

5.3. Proper environmental survey

The government of Nigeria through the Federal Ministry of Niger Delta Affairs and the Niger Delta Development Commission (NDDC) and the respective state governments represented in the Niger Delta as a region should as a matter of urgency commission another Niger Delta Environmental Survey which shall be called the New Niger Delta Environmental Survey (NNEST) to build on the Niger Delta Environmental Survey of 1996. This survey shall be driven by local scientists and significant consultation with the people of the coastal communities must be consequential. The international collaboration should involve bodies such as the United Nations Environment Programme (UNEP), Wild Life Fund (WLF), Home of Mother Earth Foundation (Homef) and Amnesty International to serve as observers and ensure the integrity of findings.

6) CONCLUSION

This review paper has looked at the problem of data reliability in the Niger Delta region of Nigeria with a view to ascertaining the reasons for discrepancies in the data reported for oil spill incidents in the Niger Delta region of Nigeria as a start off point to providing lasting solutions to

the problem of oil spill in the region. The review looked at the state of the Niger Delta region in terms of its description and its socio-economic state. Oil spill data from three key sources were analyzed to identify sources of inconsistency in the reportage. Inconsistency was found in data reported by various organizations which ultimately serves to erode the already fragile confidence in the available data for advocacy, research or prosecution purposes.

This review opines that the most viable solution to the perennial problem of oil spills in the Niger Delta calls for serious and significant investment in infrastructure for oil spill data gathering. This will feed into planning the transport and storage of crude oil and the attendant finished products. These must also be supported by the use of contemporary technologies to tackle emerging oil spill related problems in the region. These significant investments must be accompanied by strategic and systematic actions that specifically eliminate the persistent problem of oil spill in the Niger Delta by methodically and deliberately engaging the oil producing host communities for long lasting impacts.

It is the view of this review that the multi-agency approach to managing oil spill incidents creates a red tape situation which rather impedes the effective and efficient management of oil spills in the country with particular concern for the Niger Delta region. Clear cut plans that are strategic and systematic in their implementation with increased investment in upgrading oil transport infrastructure and security is the only viable and lasting solution to the problem. Arising from the content of this review, which has aptly shown the inconsistency in data reporting, this study recommended the adoption of powerful modelling software to monitor oil spills as well as the use of geospatial techniques, community engagement and proper environmental surveys of the region.

Conflicts of Interest: The authors declare that they have no conflict of interest

REFERENCES

1) Naanen, B. and Tolani, P., 2014. Private gain, public disaster: social context of illegal oil bunkering and artisanal refining in the Niger Delta.
2) Ozigis, M.S., Kaduk, J.D. and Jarvis, C.H., 2019. Mapping terrestrial oil spill impact using machine learning random forest and Landsat 8 OLI imagery: A case site within the Niger Delta region of Nigeria. *Environmental Science and Pollution Research*, *26*(4), pp.3621-3635.
3) Byrne, R., 2019. The impact of oil spills: Research Briefing. Research Service National Assembly for Wales Tŷ Hywel Cardiff Bay CF99 1NA. Available online at www.assembly.wales/research
4) Hernawan U, Risdianto RK. 2020. Oil spill contingency plan (OSCP) by environmental sensitivity index (ESI) analysis at East Barito District, South Barito District and Kapuas District (Tamiang Layang, Buntok and surrounding area), Central Kalimantan Province. InIOP Conference Series: Earth and Environmental Science 2020 Jun 1 (Vol. 500, No. 1, p. 012026). IOP Publishing.
5) Oyegun, C. and Lawal, O., 2017. Geographic information systems-based expert system modelling for shoreline sensitivity to oil spill disaster in Rivers State, Nigeria. *Jàmbá: Journal of Disaster Risk Studies*, *9*(1), pp.1-8.
6) Akpokodje, E. G. (2020). A Sustainable Niger Delta: Still Possible Only If… A Valedictory Lecture. Department of Geology, Faculty of Science, University of Port Harcourt. Valedictory Lecture Series No 15. 24th August, 2020
7) Wekpe, V.O. 2018. Festival of Pollution in the Niger Delta. In Elenwo, I.E and Ochege, F.U (Eds) (2018) Environment, Resources and Sustainability in the Niger Delta Region, Nigeria. (Port Harcourt, University of Port Harcourt Press).
8) Kornom-Gbaraba., M. E and Aernan, J. E. 2021. Causes of Oil Pipeline Leakages and Their Effect on Economic Growth in Nigeria. International Journal of Latest Engineering and Management Research. (5), 87-95
9) Ite, A. E., Ibok, U. J., Ite, M. U., and Petters, S. W. 201). Petroleum exploration and production: Past and present environmental issues in the Nigeria's Niger Delta. American Journal of Environmental Protection, 1(4), 78-90.
10) Watts, M., Zalik, A. 2020. Consistently unreliable: Oil spill data and transparency discourse. The extractive industries and society, 7(3), 790-795.
11) Amnesty International. 2012. Oil Spill Investigations in the Niger Delta Amnesty International Memorandum September 2012
12) Amnesty International. 2015. Niger Delta: Shell's manifestly false claims about oil pollution exposed, again. Available online on https://www.amnesty.org/en/latest/news/2015/11/shell-false-claims-about-oil-pollution-exposed/. Last accessed 24/11/2020.
13) Elekwachi, W., Nwankwoala Hycienth, O., Ocheje Johnmark, F., and Onyishi, C. J. 2019. Oil Spill Incidents and Wetlands Loss in Niger Delta: Implication for Sustainable Development Goals. International Journal of Environment and Pollution Research, 7(1), 1-20.
14) Eziukwu, A. 2015 Bonga oil spill affected 168,000 people in 350 communities — Monarch. Premium Times. April 6 2015. Available online at https://www.premiumtimesng.com/regional/south-south-regional/180674-%E2%80%8Bbonga-oil-spill-affected-168000-people-in-350-communities-monarch.html. Last accessed 11/03/2020
15) Oviasuyi, P.O., and Uwadiae, J. 2010. The Dilemma of Niger-Delta Region as Oil Producing States of Nigeria. Journal of Peace, Conflict and Development, 16. 110-126.
16) UNEP. 2011. Environmental assessment of Ogoniland. Background to Environmental Degradation in Ogoni Land.

17) Abam, T. K. S. 2001. Regional hydrological research perspectives in the Niger Delta. Hydrological Sciences Journal, 46(1), 13-25.

18) Abam, T. K. S., Ngah, S. A. 2016. Flux Efficiency and Self Cleansing Potential of Estuarine Rivers in the Niger Delta. JNES VOL. 10, NO. 2 46

19) Abam, T. K. S. 1999. Impact of dams on the hydrology of the Niger Delta. Bulletin of Engineering Geology and the Environment, 57(3), 239-251.

20) Mmom, P. C., Arokoyu, S. B. 2010. Mangrove forest depletion, biodiversity loss and traditional resources management practices in the Niger Delta, Nigeria. Research Journal of Applied Sciences, Engineering and Technology, 2(1), 28-34.

21) NDDC, 2006. The Niger Delta Regional Development Master Plan: popular Version.

22) Onyena, A. P., & Sam, K. 2020. A review of the threat of oil exploitation to mangrove ecosystem: Insights from Niger Delta, Nigeria. Global Ecology and Conservation, 22, e00961.

23) Gil-Agudelo, D. L., Nieto-Bernal, R. A., Ibarra-Mojica, D. M., Guevara-Vargas, A. M., and Gundlach, E. 2015. Environmental sensitivity index for oil spills in marine and coastal areas in Colombia. CT&F-Ciencia, Tecnología y Futuro, 6(1), 17-28.

24) Ibe, A.C. 1988. Coastline erosion in Nigeria: The Nigerian institute for oceanography and marine research. Ibadan, University Press, Nigeria (ISBN 978-2345-041).

25) Falaye, A. 2008. Illegal, Unreported and Unregulated (IUU) fishing in West Africa. (Nigeria and Ghana). London: Marine Resources Assessment Group.

26) Oyedepo, J.O, Adeofun, C.O 2011. Environmental Sensitivity Index Mapping of Lagos Shorelines Global Nest Journal, Vol 13, No 3, Pp 277-287, 2011.

27) Kloff, S, Wicks, C., 2005. Environmental management of offshore oil development and maritime oil transport. Fondation internationale du Banc d'Arguin.

28) Depellegrin, D., & Pereira, P. 2016. Assessing oil spill sensitivity in unsheltered coastal environments: A case study for Lithuanian-Russian coasts, South-eastern Baltic Sea. Marine pollution bulletin, 102(1), 44-57.

29) Mba, I. C., Mba, E. I., Ogbuabor, J. E., and Arazu, W. O. 2019. Causes and terrain of oil spillage in Niger Delta region of Nigeria: The analysis of variance approach. International Journal of Energy Economics and Policy, 9(2), 283.

30) Badejo, O. T., Nwilo, P. C. 2004. Management of oil spill dispersal along the Nigerian coastal areas. In ISPRS Congress.

31) Oyewunmi, O. A., Olujobi, O. J. 2016. Transparency in Nigeria's oil and gas industry: Is policy re-engineering the way out? International Journal of Energy Economics and Policy, 6(3), 630-636.

32) Boateng, I. 2010. Spatial planning in coastal regions: facing the impacts of climate change. Report of Federation of International Surveyors (FIG) working group 8.4. Copenhagen:

33) Oyegun, C. U. 1993. Land Degradation and the Coastal Environment of Nigeria. CATENA, 20(3), 215–225. doi:10.1016/0341-8162(93)90001-6

34) Musa, Z. N., Popescu, I., and Mynett, A. 2014. The Niger Delta's vulnerability to river floods due to sea level rise. Natural Hazards and Earth System Sciences, 14(12), 3317.

35) Zabbey, N., Giadom, F.D., Babatunde, B.B 2018. Nigerian Coastal Environments in Sheppard, C. (Eds.). (2018). World Seas: An Environmental Evaluation: Volume I: Europe, The Americas and West Africa. Academic Press.

36) Kadafa, A. A. 2012. Environmental impacts of oil exploration and exploitation in the Niger Delta of Nigeria. Global Journal of Science Frontier Research Environment & Earth Sciences, 12(3), 19-28.

37) Osuagwu, E. S., Olaifa, E. 2018. Effects of oil spills on fish production in the Niger Delta. PloS one, 13(10), e0205114.

38) Olujobi, J.O. and Oyewunmi, A.E., 2018. Oil spillage in Nigeria's upstream petroleum sector: Beyond the legal frameworks. International Journal of Energy Economics and Policy, 8(1), pp.220-226.

39) Nwankwoala, H. O., Nwaogu, C. 2009. Utilizing the tool of GIS in oil spill management-a case study of Etche LGA, Rivers State, Nigeria. Global Journal of Environmental Sciences, 8(1).

40) Nwilo, P.C, Badejo, O.T., 2006. Impacts and management of oil spill pollution along the Nigerian coastal areas.

41) Central Bank of Nigeria (CBN) 2020. Crude Oil Price (US$/Barrel), Production (mbd) and Export (mbd). Available online at https://www.cbn.gov.ng/rates/crudeoil.asp. Last accessed 18/03/2020

42) Ogbonnaya, U. M. 2011. Environmental law and underdevelopment in the Niger Delta region of Nigeria. African Research Review, 5(5), 68-82.

43) Chen, J., Zhang, W., Wan, Z., Li, S., Huang, T., and Fei, Y. 2019. Oil spills from global tankers: Status review and future governance. Journal of cleaner production, 227, 20-32.

44) Oyedepo, S. O. 2012. Energy and sustainable development in Nigeria: the way forward. Energy, Sustainability and Society, 2(1), 1-17.

45) Agbakwuru, J. 2011. Pipeline potential leak detection technologies: assessment and perspective in the Nigeria Niger Delta region. Journal of Environmental Protection, 2(08), 1055.

46) Nigeria Country Analysis Brief. 2020. Available online at https://www.eia.gov/international/analysis/country/NGA. Last accessed 01/12/2021

47) Tamuno, S.O, Edoumiekumo , S.G 2012 Nigeria in the Niger Delta: An Allegory of the "Legs Tying the Hands" International Review of Social Sciences and Humanities 4(1), 113-120

48) U.S. Energy Information Administration. 2020. Nigeria energy outlook 2020.

49) Guo, Y., Zhang, H. Z. 2014. Oil spill detection using synthetic aperture radar images and feature selection

in shape space. International Journal of Applied Earth Observation and Geoinformation, 30, 146-157.

50) Griggs, J.W. 2011. BP Gulf of Mexico oil spill. Energy L. J., 32(1), 57-80

51) Upton, H. F. 2011. The deepwater horizon oil spill and the Gulf of Mexico fishing industry. CRS Report for Congress. Congressional Research Service. 7-5700. R41640.

52) Bayramov, E., Kada, M., and Buchroithner, M. 2018. Monitoring oil spill hotspots, contamination probability modelling and assessment of coastal impacts in the Caspian Sea using SENTINEL-1, LANDSAT-8, RADARSAT, ENVISAT and ERS satellite sensors. Journal of Operational Oceanography, 11(1), 27-43.

53) Ogiriki, S. O., Adepoju, J. O., Yusuff, A. S., and Anochie, V. 2018. Physical Properties of Agbabu and Yegbata Bitumen in Nigeria. Journal of Applied Science & Process Engineering, 5(1), 227-241

54) Mehanna, A. K., Hegazy, E. H., Omar, M. Y., Hassan, A. A., Elkilani, H., and Turki, E. A. 2013. Modelling of oil spill impacts on shoreline in Egypt. In Developments in Maritime Transportation and Exploitation of Sea Resources–IMAM 2013 Conference, A Coruña, Spain (pp. 14-17).

55) Alpers, W., Holt, B., & Zeng, K. 2017. Oil spill detection by imaging radars: Challenges and pitfalls. Remote Sensing of Environment, 201, 133-147.

56) Yeeles, A., Akporiaye, A. 2016. Risk and resilience in the Nigerian oil sector: The economic effects of pipeline sabotage and theft. Energy Policy, 88, 187-196.

57) Larsen, P. T., Pedersen, F., Dorge, J., Andersen, M. B., Lintrup, M. J., Rasmussen, D., and Muller, L. 2000. Environmental spill modelling and risk assessment of Orimulsion 400 and Heavy Fuel Oil. WIT Transactions on Ecology and the Environment, 44.

58) Kankara, R. S., Subramanian, B. R., Sampath, V., & Ramachandran, S. (2003) Oil spill risk assessment and sensitivity analysis for Gulf of Kachchh, India.

59) Fabiyi, O.O. 2008. Mapping environmental sensitivity index of the Niger delta to oil spill; the policy, procedures and politics of oil spill response in Nigeria. Proceedings of Map Africa 2008 Conference. 1-20.

60) Denedo, M., Thomson, I. and Yonekura, A., 2018. Accountability, maps and inter-generational equity: evaluating the Nigerian oil spill monitor. Public Money & Management, 38(5), pp.355-364

61) Lehr, W., Jones, R., Evans, M., Simecek-Beatty, D., and Overstreet, R. 2002. Revisions of the ADIOS oil spill model. Environmental Modelling & Software, 17(2), 189-197.

62) Mohaghegh, S. D. 2018. Contribution of Artificial Intelligence and Machine Learning in US DOE's Efforts During the Aftermath of Deepwater Horizon. In SPE Annual Technical Conference and Exhibition. OnePetro.

63) Elizaryev, A., Maniakova, G., Gabdulkhakov, R., Elizareva, E., Longobardi, A., Nurutdinov, A., & Khakimov, R. 2018. Numerical simulation of oil spills based on the GNOME and ADIOS. International Journal of Engineering and Technology (UAE), 7(2), 24.

64) Nelson, J. R, Grubesic, T. H. 2017. A repeated sampling method for oil spill impact uncertainty and interpolation. International Journal of Disaster Risk Reduction, 22, 420-430.

65) Maitland, A, Chapman, M., 2014. Oil spills in the Niger Delta: Proposals for an effective non-judicial grievance mechanism.

66) DPR 2018. Department of Petroleum Resources 2018 Nigerian Oil and Gas Industry Annual Report. DPR Towers Victoria Island Lagos, Nigeria.

67) Olawuyi, D.S, Tubodenyefa, Z., 2018. Review of the Environmental Guidelines and Standards for the Petroleum Industry in Nigeria (EGASPIN).

68) Olujobi, O.J. 2017. Legal framework for combating corruption in Nigeria-the upstream petroleum sector in perspective. Journal of Advanced Research in Law and Economics (JARLE), 8(25), pp.956-970.

69) Fingas, M., Brown, C. E. 2018. A review of oil spill remote sensing. Sensors, 18(1), 91.

70) Sun, S., Lu, Y., Liu, Y., Wang, M., and Hu, C. 2018. Tracking an oil tanker collision and spilled oils in the East China Sea using multisensor day and night satellite imagery. Geophysical Research Letters, 45(7), 3212-3220.

71) Adamu, B., Tansey, K., and Bradshaw, M. J. 2013. Investigating vegetation spectral reflectance for detecting hydrocarbon pipeline leaks from multispectral data. In Image and Signal Processing for Remote Sensing XIX (Vol. 8892, p. 889216). International Society for Optics and Photonics.

72) Mursalin, M., Nurjaya, I. W., and Effendi, H. 2014. Analisis Sensitivitas Lingkungan Oscp (Oil Spill Contingency Plan) Di Pesisir Selatan Delta Mahakam, Provinsi Kalimantan Timur. Jurnal Pengelolaan Sumberdaya Alam dan Lingkungan (Journal of Natural Resources and Environmental Management), 4(1), 84.

73) Adamu, B., Tansey, K., and Ogutu, B. 2015. Using vegetation spectral indices to detect oil pollution in the Niger Delta. Remote Sensing Letters, 6(2), 145-154.

74) Adamu, B., Tansey, K., and Ogutu, B. 2018. Remote sensing for detection and monitoring of vegetation affected by oil spills. International Journal of Remote Sensing, 39(11), 3628-3645.

75) Jensen, J. R., Ramsey III, E. W., Holmes, J. M., Michel, J. E., Savitsky, B., and Davis, B. A. 1990. Environmental sensitivity index (ESI) mapping for oil spills using remote sensing and geographic information system technology. International Journal of Geographical Information System, 4(2), 181-201.

76) Robbe, N., Hengstermann, T. 2006. Remote sensing of marine oil spills from airborne platforms using multi-sensor systems. Water Pollution VIII: Modelling, Monitoring and Management, 1, 347-355.

77) Kankara, R. S, Subramanian, B. R. 2007. Oil spill sensitivity analysis and risk assessment for Gulf of

Kachchh, India, using integrated modeling. Journal of Coastal Research, 1251-1258.

78) Nkwunonwo, U. C., M. Whitworth, and B. Baily. 2020. A review of the current status of flood modelling for urban flood risk management in the developing countries." Scientific African (2020): e00269.s

79) Gorelick, N., Hancher, M., Dixon, M., Ilyushchenko, S., Thau, D., and Moore, R. 2017. Google Earth Engine: Planetary-scale geospatial analysis for everyone. Remote sensing of Environment, 202, 18-27.

80) Kennedy, R. E., Yang, Z., Gorelick, N., Braaten, J., Cavalcante, L., Cohen, W. B., and Healey, S. 2018. Implementation of the LandTrendr algorithm on google earth engine. Remote Sensing, 10(5), 691.

81) Kumar, L, Mutanga, O. 2018. Google Earth Engine applications since inception: Usage, trends, and potential. Remote Sensing, 10(10), 1509.

82) Adeofun, C. O, Oyedepo, J. A. 2012. Environmental Sensitivity Indexing of Lagos Shorelines. COLERM Proceedings, 1, 112-122.