EVALUATION OF REMEDIATION TECHNIQUES USED FOR CONTAMINATED LANDS BY OIL SPILLS

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DEDICATION

This project is dedicated to the glory of God. His unending grace has kept me through my lifetime. It is also dedicated to everyone whose life and livelihood has been impacted by the incessant oil spills in the Niger Delta region of Nigeria.

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EXECUTIVE SUMMARY

Oil spills have been a significant menace in the Niger Delta region of Nigeria over the past few decades. These spills have occurred due to a wide range of reasons including sabotage, operational error, and equipment fault, to mention but a few. Despite existing regulations that mandate oil companies to be responsible for the cleanup of oil spills, only a minute portion of contaminated lands in this region have been remediated. This has caused untold hardship to residents of the communities in this region as their primary source of livelihood, farming, and fishing, are consistently lost to these incidents. Therefore, this study evaluated the remediation techniques that have been adopted across the region and globally to determine the appropriate techniques that would be suitable for this particular region.

Before this study, most research had focused on single techniques, and each technique had their limitation. It was unclear whether a holistic approach to the policy regulating oil companies' operations and a multidisciplinary strategy to choice of remediation techniques could improve the situation. A review of published articles in the news, journals, and regulatory policies was conducted to determine how best to tackle this task. The various reviews showed that the nature of spills and circumstances surrounding each spill in this region was complex. Also, remediation techniques adopted for the region's cleanup were not documented. The review of other major oil spill incidents worldwide showed that each remediation technique has its major demerits but can be adapted to meet restoration goals.

The study developed a framework based on five criteria: timeframe, climate/geography, efficiency/effectiveness, associated costs, and environmental considerations. The study concluded that, indeed, a complex problem could not be solved with a simple solution which means a range of remediation techniques may need to be adopted for each spill incident. This study will inform decision-makers and oil companies of the need to review existing cleanup operation policies and procedures for optimal results.

1.0 Introduction

About 40 million liters of crude oil are lost across the Niger Delta each year, with a total of 7,943 spills recorded between 2006 and 2019 and about 24,000 barrels of crude oil lost in 2019 alone (The Guardian, 2019; NOSDRA, 2022). Crude oil is an easily accessible source of energy that has made life comfortable and is naturally found in several parts of the world (Xue Zhi et al., 2020). However, many accidental and sometimes non-accidental spillages occur during the exploration and transportation of crude oil.

(Marinescu et al., 2010) reports that approximately 80% of lands globally are affected by products of petroleum origin, mainly hydrocarbons. Even though many spills occur on water, as eight of the ten largest oil spills in history have occurred on water (Wikipedia 2022), this report focuses on land because of the importance of the mangrove swamp. It is regarded as one of Africa's most diverse ecosystems but has been put at risk (The Guardian, 2019). When oil spillage occurs, crude oil covers the soil surface, which causes a decrease in soil porosity, thus affecting soil respiration. Hence, carbon dioxide produced by living organisms is retained in the soil (Ezeji, 2007). Also, several other soil physical and chemical properties such as permeability are altered during oil spills, decreasing soil productivity. The leakage of spilled oil from the soil into groundwater also poses a risk to human health, vegetation, and other biological life.

Figure 1*: Oil spill at Goi Creek, Nigeria, August 2010 (Credit: Flickr.com)*

In the Niger Delta region of Nigeria, where about a three-quarters rely on farming and fishing as a means of income (The Guardian, 2019), a lot of the lands have been lost to the crude oil spill, as seen in Figure 1 . The agency responsible for monitoring oil spill detection and response in Nigeria mandates that oil companies are responsible for the cleanup of spills irrespective of the cause. These oil companies are also responsible for paying compensation to host communities who are the victims of oil spills where operational error and equipment faults lead to spills. However, there is often a clash, mutual distrust, spillage underreporting and underestimation on the part of the oil companies, (Premium Times, 2021).

This report, in part, reviewed the remediation of various spills that have occurred across sites in Nigeria and also investigated the policy or protocol that serves as a guide to oil companies when they carry out remediation of contaminated lands. Several techniques have been developed to remove crude oil from contaminated lands, classified under three broad categories; physico-chemical, thermal, and biological methods. Each of these methods has been used successfully in different countries, and there may still be some developments underway, but there are limitations to each method (Farraji et al., 2016).

It is currently unknown whether a multidisciplinary adoption of remediation techniques would help reclaim the lands in the mangrove swamp of the Niger Delta, as other researchers have focused on selecting a single technique that best suits the environment. The remediation of contaminated land in the Niger Delta has a time factor in view. As a result of a United Nations publication in 2011 claimed that it could take 25 to 30 years to clean up pollution from more than 50 years of oil operations in the region (UNEP, 2011). Thus, this research focused mainly on evaluating accepted remediation techniques for oil spills, with applicability in a Nigerian situation as the case study.

1.1 Specific Objectives

The main aim of this project was to "evaluate different remediation techniques used in treating contaminated lands from oil spills and advise a strategy adaptable for a developing country like Nigeria." In order to achieve this goal, the specific objectives will be:

- To assess the extent and scope of oil spill events from several locations across different continents, including Nigeria.

- To review several case studies in order to determine the options for remediating significant spill events in terms of applicability to a Nigerian context.

- To determine the feasibility of each remediation technique and develop a framework to support the recommendation of the most suitable remediation technique(s) for Nigeria.

1.2 Methods

To achieve the objectives above, this study will be broken down into the following category:

- To assess the extent and scope of oil spill events from several locations, a literature review was conducted from published and unpublished gray literature. By assessing the extent and scope of oil spill events from different locations, comparisons were made among significant oil spill events in Nigeria

- To review several case studies on options for remediating significant spill events, a literature search was also conducted, in connection with professionals with relevant experience. This will guide in understanding how different oil spill events have been managed, and the results of the remediation techniques that have been applied may be evaluated.

- To achieve the third specific objective, different remediation techniques that have been applied to different spill events were analyzed under the context of time, climate, effectiveness, associated costs, and environmental considerations. This was done to develop a framework that will guide the identification of the most applicable remediation techniques for significant oil spill events in a developing country like Nigeria.

2.0 Assessment and Cause of Oil Spills in the Niger Delta

The Premium Times, (2021) reported that an equivalent of 6.5 million liters of oil was spilled in the Niger Delta by 30 oil companies between January 2019 and May 2021. According to this publication, as seen in Figure 2, the primary cause of the spill was sabotage/theft, with about 74% of cases. At the same time, corrosion, equipment failure, and operational error were considered minor causes, accounting for about 20%. However, (Mongabay, 2022) reports that the oil industry's monitoring of and response to spill incidents are poor. A significant factor in the issue of continuous spills in Nigeria results from the oil majors selling aging infrastructure through divestment to locally owned companies that are ill-equipped to operate safely.

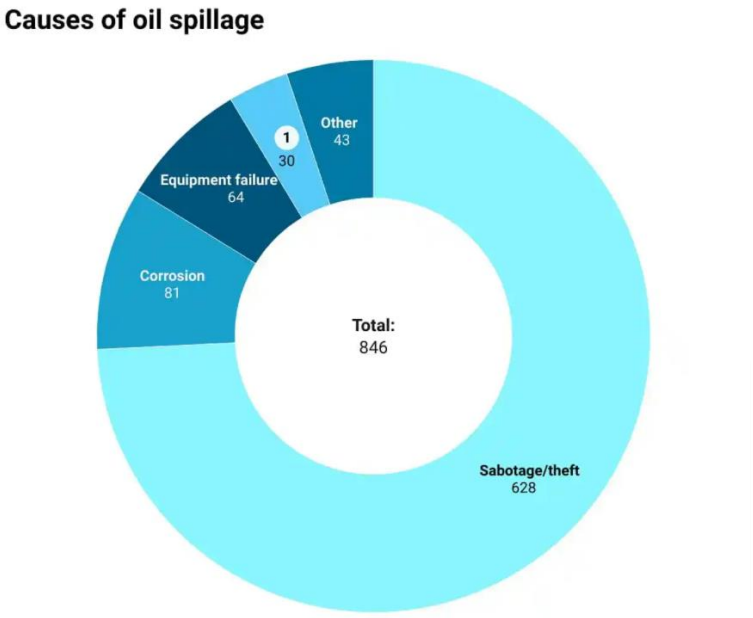

Figure 2: *Chart showing causes of Oil Spillage in the Niger Delta between January 2019 and May 2021. (Source: Premium Times, 2021)*

The country was reported to have spent about 36 million US dollars repairing vandalized pipelines between January 2019 and January 2021 (Premium Times, 2021). Despite these efforts, oil spill persistence has only meant that operational errors and equipment failures may be the actual major cause of this menace. It is unclear whether there is a protocol in place for oil companies in Nigeria to carry out a routine inspection of their pipelines where they could report about the state of their infrastructure , similar to the procedure described by AP News, (2022). In an attempt to cover up

the under-reporting of oil spills, oil companies have been indicted for using white sand to cover spill sites for remediation.

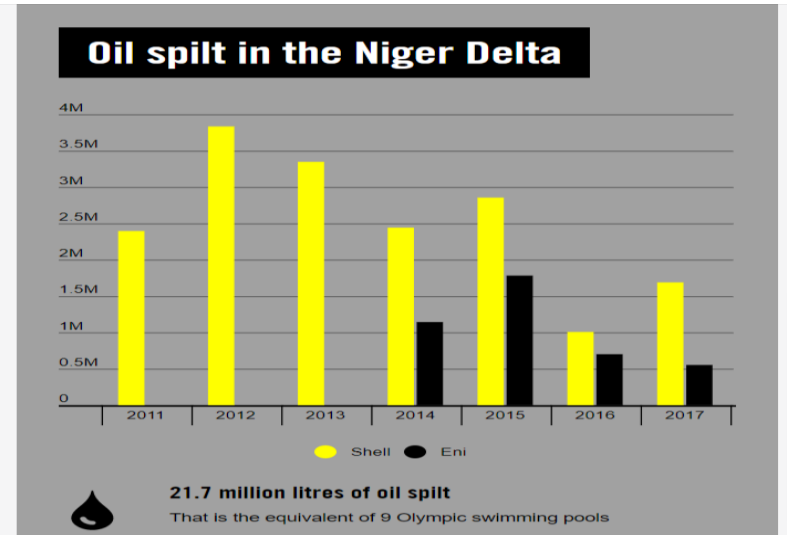

Figure 3: *A chart showing the volume of oil spilled by two major oil companies, Shell and ENI, in the Niger Delta of Nigeria between 2011 and 2017. (Source: Amnesty International, 2018)*

The Niger Delta, which is rich in biological diversity and natural resources, is said to be one of the most polluted places on earth (Amnesty International, 2018; Mongabay, 2021). As a result of excessive contamination of multiple lands from the oil spills, about 5 to 10% of the Niger Delta mangrove swamp has been lost to spills (Premium Times, 2021). Incidences of gas flaring lead to multiple events of acid rain, while oil spills contaminate both farmlands and water bodies, placing them as the 17th largest producer of greenhouse gas emissions in the world (Carbon Brief, 2020). This has made life difficult, particularly for the majority who live in this highly productive ecosystem, as their sources of income have been negatively impacted. Four of the six states with the highest unemployed population in Nigeria are states within the Niger Delta (Premium Times, 2021). Anna and Roland, (2019) provided evidence suggesting that the effects of oil spills on neonatal mortality persist for several years after the occurrence of an oil spill. Their study indicated that nearby oil spills that occur before conception increase neonatal mortality by doubling the rate. The spills also lead to a loss of revenues and place a substantial financial strain on Nigeria due to the excessive amount spent on repairing vandalized pipelines.

A major limitation in understanding the extent of spills in Nigeria is the lack of data on the number of total rehabilitated spill sites or the ones underway and the type of techniques adopted for each

cleanup operation. Despite having a website to monitor and record oil spill incidences, the Nigerian Oil Spill Detection and Response Agency (NOSDRA) does not have enough data to help compare and assess spills in the Niger Delta with other spills. This could have been pivotal in understanding the loopholes of the remediation techniques and their effectiveness on various spill sites.

2.1 Process of Reporting and Cleaning up Oil Spills in Nigeria

Based on information published on the NOSDRA website, when an oil spill occurs, the law requires that the oil company responsible for that facility should close off the site within 24 hours of the incidence awareness. Subsequently, concerned government agencies, stakeholders of the host community where the facility is domiciled, and oil company representatives are expected to form a Joint Investigative Visit. (JIV). The JIV team is responsible for assessing the spill site to determine the spill's scale, cause, and impact and proceed to sign off on a document that stands as the basis for further legal steps or compensation, if any is required.

The oil company then goes ahead to notify the government regulator within two weeks of the spill about the area covered by the spill, quantity of oil spilled, cause, recovered oil quantity, and the cleanup measures they plan to adopt. The oil company contacts the government regulator when their cleanup efforts are deemed complete by providing a report on their operations. This process, however, seems inadequate based on a few challenges that are discussed below in the next section.

Even though there is a current strategy/procedure in place for cleanup operations, its ineffectiveness calls for concern and the need for further action. News published by Amnesty International, (2018) revealed the issue of slow response times to oil spills by oil companies despite the responsibility that oil spills should be visited within 24 hours. Massive delays were detected before a response to the spill, as it was reported that there are spills that are left for months before a visit. According to Amnesty International, two major oil giants in the Niger Delta, Shell, and ENI, were particularly guilty of this act. Shell was recorded to have visited a spill site within 24 hours on 26% of occasions, and another spill took 430 days before ENI visited the facility where the spill occurred.

One of the possible actions that can be taken might be to look outside the country's shores to reflect on how this kind of situation has been managed successfully in other environments. Policy

comparison can then be made to see if implementing such in the Niger Delta would improve the situation of events. The **Alberta Energy Regulator** (AER, 2022) has a series of processes on its website called the *'Reclamation Process and Criteria for Oil and Gas Sites,'* which are a set of procedures to guide companies through remediation and further reclamation process. Key components of the process include the '*Remediation'* according to preset guidelines and a '*Reclamation Certificate,'* which is issued as a badge to certify that a land has been restored and that all reclamation requirements have been met.

3.0 Analysis and Synthesis of Oil Spills and Remediation Techniques Worldwide

3.1 Case Study I – Rice University Scientists' Use of Pyrolysis to Convert Oily Soil into Fertile Ground

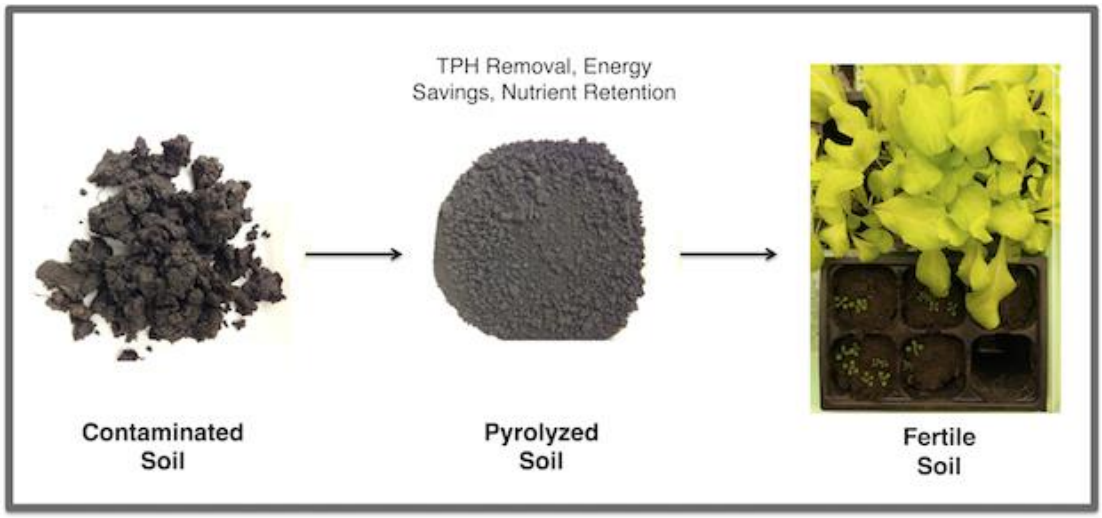

Figure 4: *Image showing the transformation of oil-contaminated soil into a fertile soil by reducing its petroleum hydrocarbon through pyrolysis* (Source: Rice University, 2015).

Rice University (2015) has developed Pyrolysis innovation which is a method of heating contaminated soils in the absence of oxygen to help reclaim oil contaminated soil and enhance the fertility of the soil. Apart from fertility reclamation, another advantage of the said pyrolysis was the energy-saving ability, deemed as more environmentally friendly than other methods, such as incineration when quick remediation is required. The publication asserted that pyrolyzing contaminated soil reduced petroleum hydrocarbon to "well below regulatory standards – below 0.1% by weight" after three hours.

In the pyrolytic process, the soil is heated to above 420 ^{o}C, and the desorption of lighter hydrocarbons is said to occur first. Above 350 ^{o}C, further cracking and condensation of high-molecular weight hydrocarbons follow. This leaves some hydrocarbons in the soil but in a mild solid form which forms some beneficial char and coats the soil, as seen in Figure 4. The pyrolytic process is considered an energy-saver because introducing oxygen to the heating process, which destroys every hydrocarbon present, requires 40% to 60% more energy. Also, the introduction of oxygen is said to destroy the soil and may convert oily soil into a rather useless desert sand. In the case of pyrolysis, the soil fertility is enhanced as the remaining carbon in the soil is turned into

char, somewhat different from the usual biochar. The retained carbon and nutrients help to enhance plant growth.

The reclaimed soil may be used for other green purposes and not food, but it could serve the purpose of planting flowers and grasses and restoring vegetation. Even though the experiment was conducted in the laboratory, the pyrolytic remediation method may be adapted to field scale by using existing technologies for thermal desorption, according to one of the authors. Few modifications may be made to the field-scaled thermal desorption unit and converted for pyrolysis.

3.2 Case Study II – Reclaiming Spilt Oil (Emily Skinner)

A news article published by the Royal Society of Chemistry (Skinner, 2013) claimed that sand contaminated by oil could be cleaned with the aid of a surfactant, and the oil would be released on demand. This is considered "a less wasteful" remediation method compared to excavation and washing, where oil emulsion is disposed of as hazardous waste. For this remediation technique, certain chemicals called ‘switchable surfactants’ are used to allow oil and water to separate. However, the surfactants have to be anionic because of the negative surface charges on sand.

This technique, where oil is first recovered from land before carrying out other remediation activities, will likely decrease the cost of the remediation process. The final bottleneck to be resolved was finding a way to decrease the processing temperature from 50 ^{o}C to make the solution more practicable at the field scale.

3.3 Case Study III – Understanding Oil Spills and Oil Spill Response (US Environmental Protection Agency)

The US EPA (1999) publication discussed biological remediation options as a technique to clean up shorelines after an oil spill. In this article, biodegradation ,which involves soil microorganisms “eating up” hydrocarbons of petroleum, is confirmed to work well in warm environments and even better with stimulation. Biostimulation involves the introduction of fertilizer compounds like nitrogen and phosphorus into oil-contaminated soil in order to encourage organisms to grow and reproduce. This resulting increase in the population of the organisms, in turn, aid the pace of the natural biodegradation process. Another bioremediation intervention is augmentation.

Bioaugmentation involves the introduction of non-native microorganism species to increase the population of hydrocarbon utilizing bacteria (HUB) (refer to Figure 5).

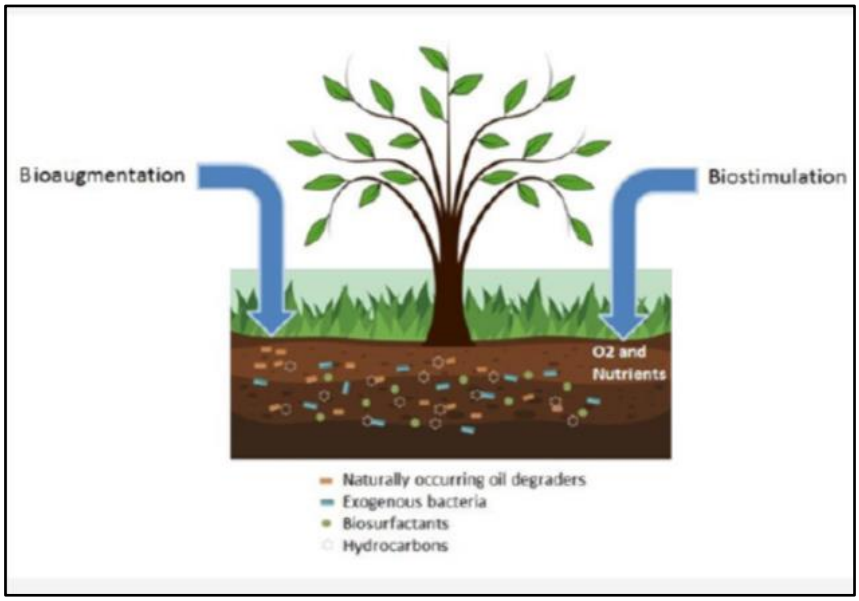

Figure 5: *Approaches to accelerating microbial degradation of petroleum in the soil (Source: Xue Zhi, 2020)*

The Exxon Valdez oil spill in California in 1989 adopted the bioremediation option of biostimulation. No water eutrophication was recorded despite the well-known fact that an increase in nutrients leads to water eutrophication. Also, the Delaware Bay oil spill in 1994 was remediated using both biostimulation and bioremediation. The biostimulation resulted in a several-fold increase in the rate of oil degradation as against the bioaugmentation. The study highlighted the environmental concern associated with the in-situ burning of oil in the aftermath of an oil spill, as it releases pollutants into the atmosphere, which requires careful air quality monitoring.

It is important to state emphatically that some oil spill cleanup may potentially harm the environment and humans more than the actual spill. In this scenario, the decision may be to allow the oil to degrade naturally.

3.4 Case Study IV – Nornickel Begins Land Reclamation of Soil Contaminated by Oil Leak

An online publication, Arctictoday, (2021) described plans to reclaim the soil back to its initial condition following soil contaminated by 23.6 million liters of oil that was spilled in Norilsk in May 2020. The oil spill occurred due to the support column for the oil storage tank sinking in the

basement of an energy company's power plant. The reclamation project had as its main goal – 'the restoration of the fertile layer and natural ecosystems in the region.'

In this reclamation project, phytoremediation was used as the remediation technique to restore the natural ecosystems after the top contaminated soil has been removed using excavators and bulldozers. Phytoremediation is a remediation technique engineered by sun energy by using plants to remove contaminants from the soil of the vastly contaminated area, and it has been proven effective (Xue Zhi, 2020). Plants' ability to survive in a contaminated soil environment through metabolism and accumulation of the toxic compounds in their roots is explored through phytoremediation (De Boer, 2016). The effectiveness and efficiency of phytoremediation are functions of several factors, including plant species selection, environmental conditions, and rhizobacteria (Farraji et al., 2016). As a result, the choice of plants to consider for phytoremediation depends on extended root systems, ability to adapt to different environmental conditions, little water requirement, and rapid growth rate (Escobar-Alvarado, 2018).

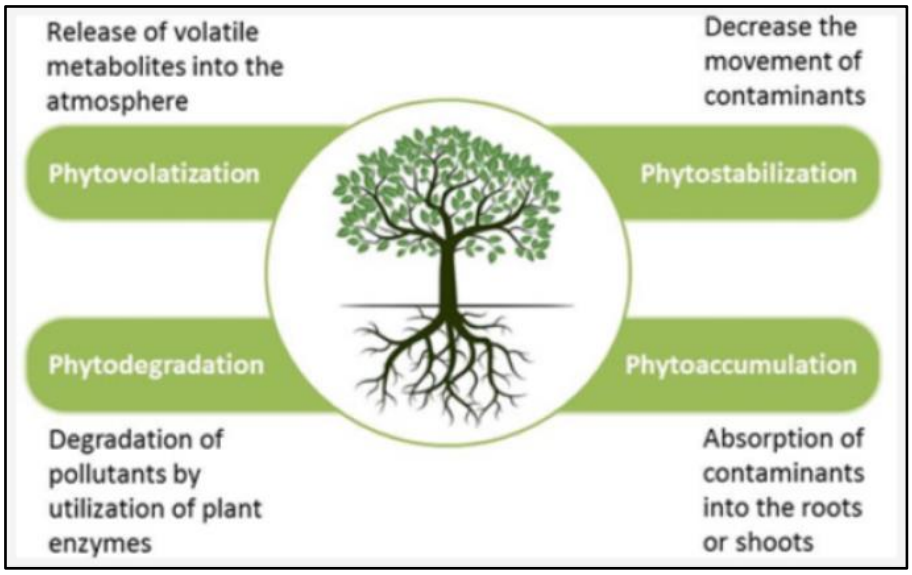

Figure 6: *Several strategies by which plants carry out contaminant removal (Source: Xue Zhi, 2020)*

3.5 Case Study V - Bioremediation of Soils Saturated with Spilled Crude Oil (Radwan *et al.*, 2020)

Radwan *et al.,(*2020) carried out a study to determine if microbial biodegradation of crude oil in oil-saturated soils (OSS) would proceed and if the dilution of oil concentration through the addition

of oil-free soil would affect the rate of degradation. In this study, bioremediation was adopted because of the adverse effects associated with other physical and chemical remediation methods, although they had to first remove a significant portion of spilled oil. Environmental friendliness and cost-effectiveness were some of the parameters that made bioremediation a suitable option in their study. Air pollution through incineration and possible groundwater contamination was identified as a concern for landfill options of excavated soil. Moreover, the topsoil, where the major biological activity occurs is usually lost during the excavation of oil-contaminated soil (Kuiper et al., 2004; Wang et al., 2011; Rosenberg, 1993).

Even though there are concerns about the release of CO_2 into the atmosphere during biodegradation by bacteria, the article posited that only a part of the crude oil's carbon is released into the atmosphere. The other carbon part is said to be stored in the soil as a cell material for the microorganism. For the bioremediation carried out in this study, desert soil was contaminated with 17.3% of oil as this was the concentration required to saturate the soil fully. Oil-free soils (desert soil and garden soil) were also added to the contaminated soil to varying degrees of dilution in order to determine the rates of degradation at different concentrations.

This study revealed that microbial degradation indeed occurred in oil-saturated soil as the oil-removal values presented in their study were all significant. It was observed that between 16 to 18% was consumed in the first month, and 53 to 79% of the oil was consumed based on initial concentration within the second to seventh month of the study. This was attributed to the fact that heavily contaminated sites from oil self-enriches the soil with strains of bacteria capable of tolerating such high concentrations. The study also revealed that there was no significant difference between removal rates of oil between oil-saturated soils and diluted oil-saturated soils, irrespective of the type of soil used in dilution. The study concluded that heavily contaminated soils have to be kept well-aerated and moistened to sustain bacteria activity and that biostimulation could further enhance oil degradation.

4.0 Framework to Guide Remediation Techniques Choice for Applicability in the Niger Delta

Table 1: *Comparison between different remediation techniques that have been used for large-scale remediation based on five criteria to aid the selection of an integrated approach to oil spill cleanup in the Niger Delta*

Remediation Techniques	**Timeframe**	**Climate/ Geography**	**Effectiveness/ Efficiency**	**Associated Costs**	**Environmental Considerations**
In-situ burning	Usually fast and the lightness of the oil could play an important role	Good for dry environments, may not be suitable for swamps	Highly efficient in the soil's top layer, it may be an issue for oil at depth	Cost-effective as the introduction of fire is relatively cheap	Air pollution may be a concern in the environment as toxic volatile compounds are released into the atmosphere; Risk of damaging soil organisms and other properties around the contamination site
Incineration	Usually fast and the lightness of the oil could play an important role – similar to in-situ burning.	Good in dry environments, may not be suitable in swamps	Very effective in the topsoil as it usually occurs after excavation of topsoil to offsite facilities	High operational costs are involved due to the high energy required to move soil to offsite	Environmental pollution can result from the burning of heavy hydrocarbon compounds; Removal of topsoil disrupts the ecosystem as some soil beneficial soil organisms are moved offsite
Excavation	Fast – as it is often one of the	It May be helpful in swamps to stop the migration of	Highly efficient since the soil is	Very expensive, and the size of the	A major concern is the loss of topsoil in productive soils, and the new soil surface may be prone to erosion and

	first lines of response to spills	oil due to waterlogging conditions at the surface	moved with the oil	spill site could skyrocket the cost	other environmental conditions; Disruption of soil ecosystem and food chain
Surfactants	Relatively quick as it is usually part of the first cleanup steps after a spill	Surfactants are used in both land and water; waterlogging conditions may not pose a significant concern.	Highly effective in recovering oil after a spill	Available data shows that recovering oil through surfactants helps reduce the cost of further decontamination.	No data on possible environmental consequences when surfactants are used on land
Washing	Commonly used as pre-treatment and usually slow as it is done ex-situ	It May not be suitable in waterlogging conditions because water could dilute chemicals used	Efficient enough; (Wood, 2002) places efficiency at 80%	Relatively expensive due to excavation required before washing is done	Environmental concerns are linked to the excavation since washing is done ex-situ
Pyrolysis	Occurs at a fast rate; a lab study showed that	Since the unit can be adopted at a field scale, it may	Very effective; converts rest of	It May be expensive to adopt on a large	Environmentally friendly and does not render reclaimed soil unproductive, rather fertile

	concentrations were down to < 0.1% in three hours (Rice University, 2015).	be suitable in the Niger Delta region.	hydrocarbon into beneficial char	scale, but the energy requirement is relatively low since oxygen is not needed	
Bioremediation	Usually occur at a slow pace. It could take months or years	Suitable in all types of environments as microbes are often indigenous to the soil	Highly effective, especially when combined with other technique that removes the bulk of oil	Very cheap and has low energy requirements, biostimulation may increase the cost	Most environmentally friendly as CO2 released during the degradation process is partly released and partly stored in the soil.
Phytoremediation	Slow pace	Since vegetative species are used, plant species that can adapt to waterlogged conditions can be found or genetically modified.	Relatively efficient, efforts ongoing to improve efficiency through genetic modification	Cost-effective as vegetative species required are not usually expensive	Environmentally friendly approach

The five criteria used for evaluating the different remediation techniques in Table 1 were selected based on the uniqueness and circumstances surrounding oil spills in the Niger Delta.

Time – Since oil spills are deemed to be widespread in this region, and with the excessive amount of oil spilled each year, there is a need to adopt remediation techniques that have a shorter time frame to cleanup projects on time. Most of these spills have been left to natural biodegradation over time; however, there is a call for urgency in returning these contaminated sites to productivity in order to restore the livelihood of the residents affected by oil spills.

Climate – Certain remediation may not be suitable for the tropical climate/nature of soils present in the Niger Delta. This region is mainly a mangrove swamp that receives heavy rainfall of about 2500mm yearly (Odokuma and Dickson, 2002). It also contains many estuaries where the River Niger meets the Atlantic Ocean, and as a result, it is a very sensitive and delicate ecosystem. Most of the soils are waterlogged throughout the year.

Effectiveness/Efficiency – Even though there may not be enough quantitative data to back up claims on how effective each remediation technique is, it is vital to introduce qualitative measurements that have been discovered in the literature. The Niger Delta region requires remediation techniques that have been observed to be highly efficient and effective based on their introduction to other oil spill events.

Associated Cost – The significant drivers for associated costs for different remediation techniques include energy requirements, manpower, sophistication level of the technology involved, and timespan. As a developing country, it is crucial that remediation techniques that do not involve very high financial commitment are selected while also considering other criteria.

Environmental Considerations – Oil spillage on its own is an environmental concern. Therefore, since it is most likely impossible to have a remediation technique that does not pose another environmental concern, it is vital to select techniques with a minor concern and that are more environmentally friendly. Hence, this justifies the inclusion of this criterion.

5.0 Conclusion

There have been serious concerns about the lack of remediation efforts in the Niger Delta region of Nigeria which is a highly polluted environment from oil spillage over decades of operations. In a bid to address this menace, this study sought to assess the different spill incidents that have been recorded in this region as well as from other parts of the world. By assessing the spill incidents and taking a global view of major spill incidents worldwide and the adopted remediation techniques, there was optimism around finding suitable technologies to reclaim the contaminated lands. This was done to guide in having a framework that could inform policy and decisions of stakeholders.

The assessment of various spills in the Niger Delta revealed that the complex nature of spills in this region required a holistic approach to addressing different elements. The review of adopted remediation techniques for major spills worldwide also indicated that selecting the appropriate technique for a spill is not a straightforward task. More than one technique may be adopted for a single spill incidence based on the preliminary and advanced stages of cleanup operations. Therefore, the study concluded through a thorough review of the framework that integration of techniques that meet sustainability criteria should be adopted for cleanup operations in the Niger Delta region of Nigeria.

6.0 Recommendations

After a careful review of the literature, this study recommends the following:

- That the existing policy based on which oil companies carry out cleanup operations of spills be reviewed by incorporating a global perspective. Specifically, it is recommended that the approach taken by the Alberta Energy Regulator be adopted where there is the issuance of certificate and audit of cleanup efforts as a follow-up from regulatory bodies.
- Responsible parties carefully consider remediation efforts by assessing the potential for harm of the remediation procedure itself against the harm posed by the oil spill.
- Adoption of best remediation techniques should be based on a range of criteria, including the criteria demonstrated in the framework developed above.
- Proper documentation of cleanup efforts of spill incidents in the Niger Delta region.

7.0 Challenges Faced

The major challenge encountered during this project was a lack of access to data about how remediation efforts have proceeded based on the various spill incidents documented on the NOSDRA website. In most of the incidents reported, there was no concrete information about what remediation techniques were adopted and the level of completion of the cleanup operations.

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