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ECOLOGICAL IMPLICATIONS OF NON-STANDARDIZED CRUDE OIL REFINING OPERATION ON BLUE CARBON RESOURCES IN THE NIGER DELTA

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ABSTRACT: *This study, through a review of existing literature, investigates the implications of non-standardized refineries on the mangrove ecosystem in the Niger Delta region of Nigeria. The Niger Delta region is home to one of the largest blue carbon sinks and mangrove ecosystems in the world, providing important habitat for a diverse range of species and playing a crucial role in carbon sequestration. However, the presence of non-standardized refineries in the area has raised concerns about the potential environmental impacts on the delicate ecosystem. These refineries often operate without regulations or oversight, leading to pollution of waterways, destruction of habitat for various species, and disruption of the natural food chain. This study examines the specific ways in which these non-standardized refineries are affecting the mangrove ecosystem and explores potential solutions to mitigate their negative effects. Findings from this study show that non-standardized refineries in the region are significant sources of pollution, leading to mangrove destruction. The study revealed the environmental issues, risks, and ecological significance of mangroves in the Niger Delta. The study emphasized the urgent need for better regulation and enforcement to protect these important mangrove habitats from further destruction. Finally, the study concluded that protecting the mangroves of the Niger Delta is essential for the overall health of the region.*

KEYWORDS: Ecological, implication, degradation, non-standardized refinery, mangrove, blue carbon ecosystem, biodiversity, Niger Delta.

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INTRODUCTION

Blue Carbon Ecosystems (BCEs) are unique ecosystems with great capability for communities around the world to adapt to climate change (Bertram et al., 2021). The Intergovernmental Panel on Climate Change (IPCC) defines blue carbon as all biologically driven carbon fluxes and storage in marine systems that are amenable to management (*IPCC, 2019*). "Blue carbon" refers to the organic carbon that marine organisms fix from the atmosphere and store in the seas for hundreds to thousands of years. They include all marine ecosystems that contribute to climate change mitigation by sequestering excess carbon from the atmosphere (Lovelock & Reef, 2020; Beers, Crooks, & Fennessy, 2020). BCEs, such as mangroves, seagrasses, and salt marshes, play a crucial role in sequestering carbon from the atmosphere and storing it in their sediments and vegetation (Peter et al., 2021). These ecosystems not only help mitigate climate change by capturing and storing carbon, but they also provide numerous other benefits, such as coastal protection, biodiversity conservation, and livelihood support for local communities. (Sharma et al., 2022) As such, the conservation and restoration of BCEs have become increasingly important in global efforts to address climate change and promote sustainable development. (Soares et al., 2022) The extensive distribution of blue carbon ecosystems—which cover an estimated 49 million hectares and all continents except Antarctica—highlights their significance in reducing the effects of climate change (Convention on Wetlands, 2021).

Coastal blue carbon refers to the carbon held in the soils and plants of saltwater habitats, such as seagrass meadows, mangroves, and salt marshes (Duarte, Middelburg, & Caraco, 2005; NOAA, 2023). These ecosystems store carbon in their soils and sediments and have high carbon burial rates per unit area (IPCC, 2019). By effectively trapping suspended particles and the organic carbon they carry during tidal inundation, they aid in the long-term sequestration of carbon. One characteristic that distinguishes coastal ecosystem from terrestrial ecosystem is the ability of coastal ecosystems (Figure 1) "blue carbon" to store carbon for millennia, as opposed to terrestrial ecosystems' "green carbon" limited capacity to hold "carbon" for several decades or even centuries (Thomas, 2014). Blue carbon also provides many non-climatic benefits and can contribute to ecosystem-based adaptation. Coastal blue carbon ecosystems are likely to release the majority of their stored carbon back into the atmosphere if they are destroyed or damaged (Hilmi et al., 2021).

There is a scarcity of research on the causes, threats, and consequences of ongoing loss or degradation of blue carbon ecosystems in Nigeria, particularly in the Niger Delta area, where coastal resources predominate. This lack of data hinders effective conservation and restoration efforts in the region, as well as the development of sustainable management practices. Without a better understanding of the factors contributing to the decline of blue carbon ecosystems, it will be challenging to implement policies and initiatives that can mitigate the environmental and socio-economic impacts of their degradation. Therefore, further research and monitoring are essential to address this gap in knowledge and ensure the long-term health and resilience of these valuable ecosystems in Nigeria. Hence, this study is necessary. This study focused on one of the actionable blue carbon ecosystems (BCEs) in the climate context: mangrove forests. The reason for focusing on the mangrove ecosystem is because mangroves possess the highest capacity for carbon sequestration among the blue carbon ecosystems and constitute an important nature-based solution to climate change.

This study, through a literature review, examines the ecological implications of non-standardized crude oil refineries on the mangrove ecosystem in the Niger Delta region of

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Nigeria. It explores the impact of pollution and contamination from these refineries on the carbon sequestration potential of mangrove forests, which in turn affects their ability to mitigate climate change. The findings of this study will provide specific recommendations for policymakers and environmentalists, highlighting the importance of protecting mangrove ecosystems in climate change mitigation efforts. Moreover, it emphasizes the critical need for stricter regulations and enforcement to prevent further deterioration of these crucial blue carbon ecosystems, such as addressing current gaps in monitoring and implementing sustainable practices.

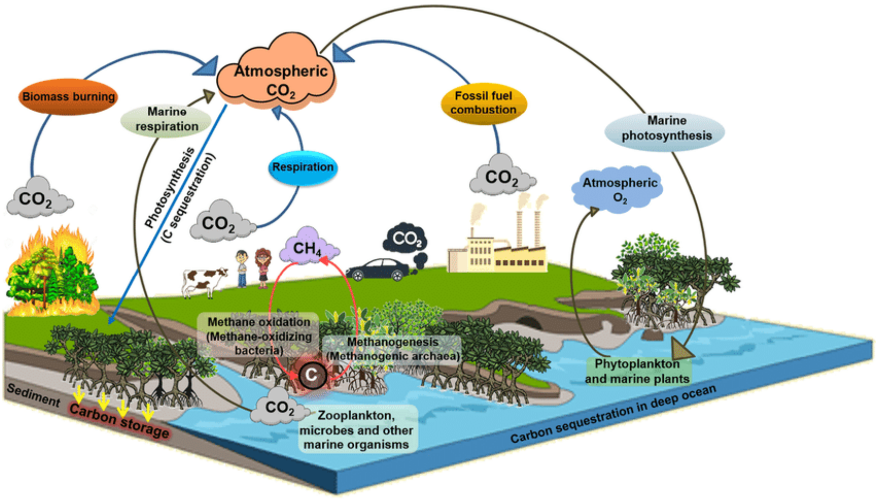

Figure 1: Coastal blue carbon cycle and the role of mangrove in removal of atmospheric CO_2 Adopted from Palit, Krishna & Rath, Sonalin & Chatterjee, Shreosi & Das, Surajit. (2022). Microbial diversity and ecological interactions of microorganisms in the mangrove ecosystem: Threats, vulnerability, and adaptations. *Environmental Science and Pollution Research.* 29. 10.1007/s11356-022-19048-7.

Mangrove Ecosystem

In terms of ecology, mangroves are collection of dicotyledonous, halophytic woody plant that are domiciled in the intertidal zone along the coast (Lonard et al. 2020). Mangroves are found in tropical and semi-tropical regions, adapted to salt water, loose, damp soils, and periodic tidal submersion (Biswas et al. 2012). As such, mangroves are defined by their environment rather than their classification. Mangroves are one of the most carbon-rich forest types in the tropics and play a critical role in addressing the triple planetary crisis of climate change, biodiversity and nature loss, pollution, and waste (Bunting et al., 2022). Mangroves create a protective green wall between land and sea, reducing the impact of storms and erosion on the coastline (Akram et al., 2022). The distribution of mangroves is determined by four main factors: soil type, tidal fluctuation, salt water, and climate (Numbere and Camilo 2019). Estimates of the global mangrove forest by Hamilton and Casey, 2016 indicated an area extent of approximately 84,000km^2 in 105 countries. Of the mangroves found in 105 countries, the South East Asia Caribbean and Brazil account for over 50% of the global mangrove forests (Hamilton and Friess, 2018).

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Mangrove ecosystems, like other forest ecosystems, represent natural capital capable of producing a wide range of goods and services, such as protection of shorelines from damaging storm and hurricane winds, waves, and floods (Menéndez et al., 2018); prevention of erosion by stabilizing sediments with their root systems; maintenance of water quality and clarity; filtering pollutants; and trapping sediments originating from land (Marois & Mitsch, 2015). Furthermore, they provide a critical source of food and economic benefit to local communities through aquaculture, apiculture, and the provisioning of fuelwood and timber (Aksornkoae & Kato, 2011). Mangroves offer a unique mechanism for capturing sediment and speeding up land-building processes in coastal and estuarine regions driven by tides; like other coastal wetlands, mangroves are powerful carbon sinks and have the highest carbon sequestration rate among all other natural ecosystems (Akram et al., 2022, Chaudhuri et al. 2019).

Mangrove Ecosystem in Nigeria

Nigeria's coastal zone includes lagoons, deltas and estuaries comprising mangrove forests and sandy beaches, with a semi-diurnal tidal regime (NDDC 2006). The Niger Delta has five ecological zones, which are mangrove forest and coastal vegetation, fresh water swamp forest, low land rain forest, derived savannah, and montane region (Ogbeibu & Oribhabor, 2023). Of these, the freshwater swamp forest is the largest and major source of timber, wildlife, fisheries, and agriculture and is highly prone to seasonal flooding (Igu, 2017).

The mangrove habitat spans around 975,000 square kilometers, from Bakassi in the east to Badagry in the west, on the low-lying ground that borders the coastal wetlands of southern Nigeria. With the marsh being anastomosed by creeks and rivers, which results in a significant inflow of nutrients and organic matter, the Niger Delta is where Nigeria's mangrove ecosystem is at its largest. Using this abundant nutritional foundation, the primary producers raise biomass. Plant communities that range in height from one to thirty-five meters make up the vegetation. *Conocarpus erectus, Laguncularia racemosa, Rhizophora mangle, Rhizophora harrisonbgii, Avicennia germinans, Nypa frutican*, *Rhizophora racemosa,* and *Rhizophora mangle* are the eight species of mangroves found in the nation in West Africa. Out of these, the Rhizophora racemosa (African red mangrove) is the most common and dominant species in the Niger Delta, while the *Avicennia germinans* species grows on the edge of river shores leading to the Atlantic Ocean (UNEP, 2007).

These mangrove species grow together in mixed form interchangeably in coastal areas in all the coastal states in Nigeria, including Lagos, Ondo, Ogun, Edo, Cross River, Delta, Akwa-Ibom, Rivers State, and Bayelsa State. Nonetheless, the population of mangroves varies among states, with Bayelsa, Delta, and Rivers states having the largest areas of mangroves (Aroloye, 2019; Numbere & Camilo, 2016). Also, associated with the mangrove swamp are other vegetation types, mostly of the families Leguminosae, Malvaceae, Euphorbiacea, Convolvulaceae, and Amarantheceae (Nodza, et al. 2021)

The ecosystem is typically low in the species richness of angiosperms, perhaps due to the inability of floral species to withstand the "harsh" periodic salinity gradient typical of the environment. However, phytoplankton, microepiphytes, benthic microalgae, and macroalgae contribute to the plant groups of the mangrove ecosystem. The Nigerian mangrove swamps harbour a great diversity of macro- and epi-fauna, of which crab and mollusc form the great majority in terms of biomass (Zabbey, & Malaquias, 2013). The faunas are faced with severe problems of water and salt balance, siltation, desiccation, oxygen availability, weight, and

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temperature limitations, especially when attempting to invade adjacent and adjoining land habitats. (Ewa-Oboho 2005) and have adapted in various ways to survive these challenges.

The Niger Delta Region of Nigeria

The Niger Delta region (Figure 2) is located at the apex of the Gulf of Guinea on the west coast of Africa in the southern geopolitical zone of Nigeria on flat, low land about 3 to 5 meters above sea level (Authority 2021). The physical environment of the region is wholly deltaic in nature and comprises nine states in Nigeria in no particular order (Fig. 1). (Weli et al. 2019). The mangrove ecosystem in the Niger Delta region is critically threatened; the mangroves in the region are declining at an alarming rate, just like mangroves elsewhere around the globe. Nevertheless, information about the hectares of mangrove forests destroyed in the Niger Delta during the previous 20 years is not easily accessible. Numerous investigators have documented noteworthy losses. Today, the activities of non-standard refineries and oil spillage arising from oil and gas exploratory activities are the main causes of mangrove devastation in the Niger Delta (Yaw & Edmund, 2006).

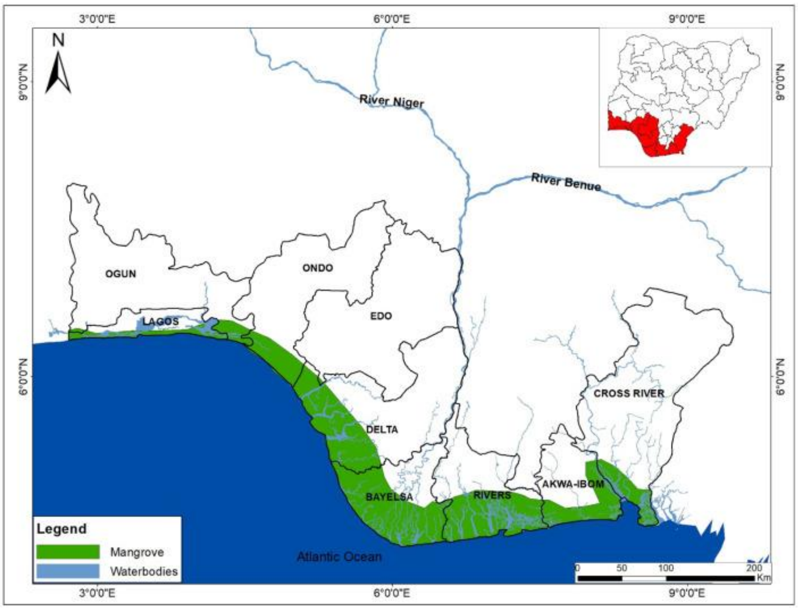

Figure 2: Map of the Nigeria's Niger Delta region showing the Mangrove Forest:

Adapted from Oweikeye, P. E. (2017). GIS-Based Mapping and Analysis of Oil-pollution in Niger-Delta Coastal Environment (M. Sc Thesis Submitted to University of Aberdeen, Scotland).

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Non-standardized Refinery

Non-standardized refining of crude oil is practices that include stealing crude oil and refining it locally using locally made materials found in the area, traditional knowledge, and skills, with little to no use of modern technology (Douglas, 2018). This process is also known locally as "kpo-fire" in the Niger Delta area. Non-standardized refineries are small, locally built structures that are capable of carrying out fractional distillation of crude petroleum over a specific range of heating points to yield usable products such as kerosene, fuel, diesel, bitumen, and waste. The process involves local skills, technical know-how, and materials with no reliance on modern technology. (Yebrade, and Tanee, 2016).

The non standardized refining process entails the deployment of locally built metal drums or tanks that can withstand extreme temperatures and heat. Connected to these drums or tanks are two parallel receiving pipes welded in at special angles to ease the evacuation of the refined product (Barenboim et al. 2015).). The technique utilizes one pipe to serve as a returning pipe and the other as an outlet for waste. It begins with putting the crude oil in the drum or tank and mixing it with some potassium chloride or sulfate and detergents, which serve as catalysts. The locally made heating drums or tanks containing the crude oil are then heated from below with burning firewood and other mixtures to attain a thermal cracking. level, which will yield fairly refined diesel, kerosene, and petrol (Nwankwoala et al. 2017). This process of thermal cracking is crucial in the production of refined petroleum products, as it helps to separate the different components of the crude oil based on their boiling points. The heat causes the molecules to break apart and recombine into lighter hydrocarbons, which can then be collected and stored for further processing. The use of specially angled pipes in the heating drums allows for more efficient evacuation of the refined product (Barenboim et al., 2015).

The operation of non-standardized refineries across the Niger Delta has given rise to an informal, highly entrepreneurial, semi-structured economic system. A unique five-stage value chain, comprising of tap installation on crude oil pipelines or manifolds, tapping point operation and security, supplying stolen crude for export and local refining, local refining into products stage, and distribution and sale of refined products, is followed by the management and operation of each locality (SDN, 2015)

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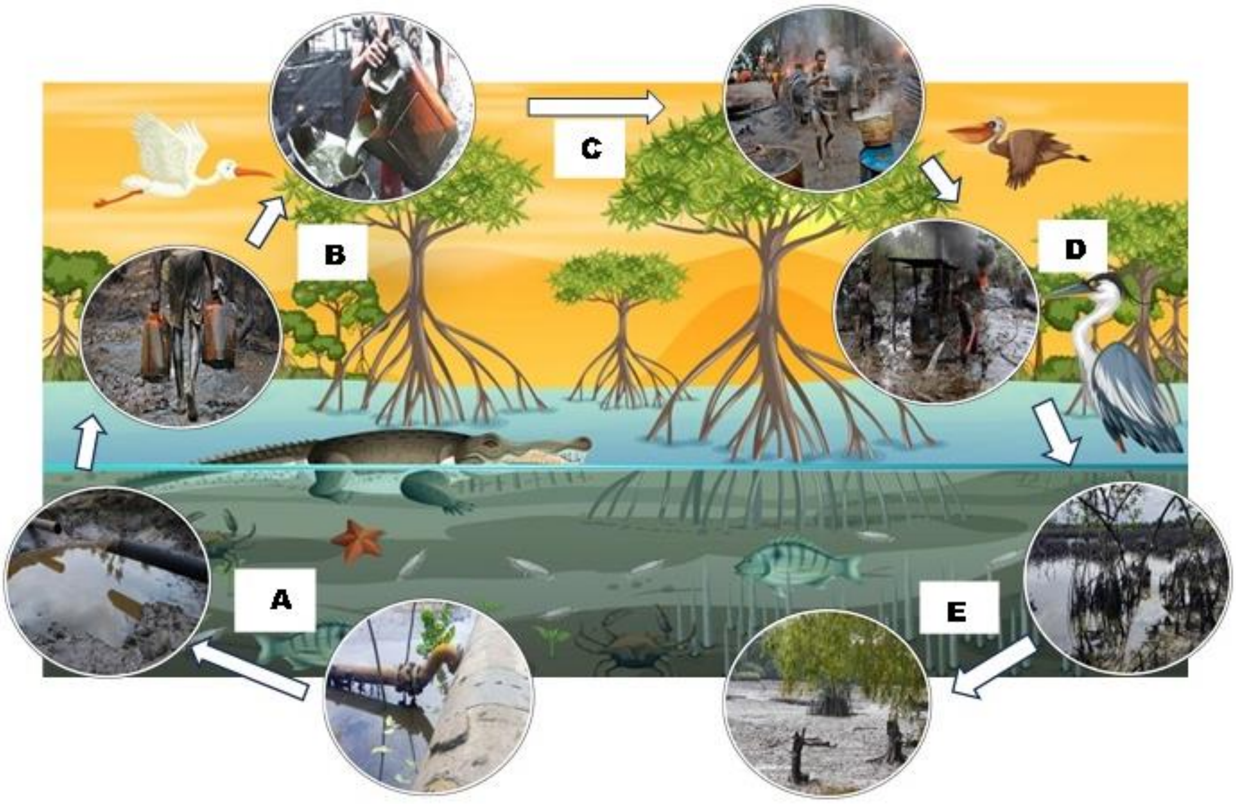

Figure 3: A schematic diagram illustrating the sequence of events leading to the contamination of mangrove ecosystems by non-standard crude oil refineries in the Niger Delta Region of Nigeria. A =Illegal siphoning of crude oil from pipelines or other oil facilities; B & C =Transportation of crude oil to nearby local refineries in the creeks; D) Local refining process causing crude oil and refined products to leak into the mangrove environment; and E) Devastation of mangroves due inefficient refining of crude or refined oil

In a typical non-standardized refinery, the production capacity is about 10,000 barrels per day. As a result of the non-use of modern technology, the process is largely inefficient, requiring little capital and a large number of untrained physical labourers. The level of inefficiency in the non-standardized refining process is unprecedented, such that in some cases, as much as 55% to 80% of the hydrocarbons, consisting of heavy carbon molecule residues of the crude oil, are left unrefined and are just poured for convenience into the nearby mangrove swamps or water bodies, thereby constituting ecological damage. (Attah, 2012). There are contaminants released into the air and water during the refining process of crude oil in makeshift facilities. The ecosystem is contaminated by harmful compounds that have an impact on aquatic life, soil quality, and the general balance of the ecosystem. Aside from the ecological danger posed by the makeshift refining process, the process of procuring crude from pipelines is also a major ecological concern. The resulting oil spills from damaged pipelines and waste from tens of thousands of non-standardized refineries combine to produce a huge ecological challenge for the blue carbon resources in the Niger Delta region. (Naanen, 2012).

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Ecological Implications of Non-Standardized Refineries operations on Mangroves

The procedure for refining of crude oil in conventional refineries around the world involves the release of effluents and produce water into the environment, this involves a strict environmental protection regime and the adherence to a number of regulations to avoid oil pollution (Duke, 2016). Because of its extreme negative environmental effects, non-standardized refining of crude in the Niger Delta is a special case (Figure 3). Non-standardized refineries' activities have a detrimental effect on biodiversity, degrading mangrove forests, and obstructing the regeneration of mangrove plant species. A significant amount of crude oil products such as polycyclic and aromatic hydrocarbons, phenols, metal derivatives, surface active compounds, sulfides, naphthalene acids, and other chemicals that have an effect on the blue carbon resources in the Niger Delta region are present in the waste that is discarded from the non-standardized artisanal refineries (Wake, 2005).

Mechanisms of Oil Toxicity to Mangroves

In order to understand how crude oil impacts mangroves, it is important to know the mechanisms of oil toxicity in mangroves. Some of the key mechanisms of oil toxicity in mangroves include interference with photosynthesis, disruption of nutrient uptake, and damage to cell membranes. These processes can result in reduced growth, reproduction, and overall health of mangrove plants, ultimately leading to ecosystem degradation. By studying these mechanisms, researchers can better assess the long-term effects of oil pollution on mangrove ecosystems and develop strategies for conservation and restoration efforts. Understanding the mechanisms will enhance our understanding of the impact and the determination of appropriate responses. While there is a general consensus that oil suffocates physically and has toxicological and physiological effects, scientists cannot agree on how much each mechanism accounts for, and this may differ depending on the kind of oil and length of time after the spill (Proffitt et al. 1997). The biological resources associated with mangroves that are in danger in a spill scenario might be impacted in two main ways: first by physical consequences and second by the actual toxicological effects of petroleum, which is similar to the oil toxicity problem for many other intertidal ecosystems.

How crude oil impact mangrove ecosystem

When oil spills into a mangrove ecosystem, it experiences physical and chemical modification due to a variety of environmental conditions, including temperature, wind, and wave currents, as well as chemical changes including advection, dispersion, and biodegradation. The weathered product of leftover oil in the coastline differs from newly spilled oil in terms of qualities due to physical and chemical changes in crude oil. The mangrove shoreline's sensitivity to oil is also significantly influenced by the terrain and environmental factors.

Spilled oil covers the aerial breathing mangrove roots inhibiting gaseous exchange and disrupting oxygen transport to underground roots leading to death of the mangrove trees. Light crude oils are known to disruption transport mechanism in mangroves and thus impairing salt exclusion in those mangroves (Page et aI., 1985). Genetic damage has also been witnessed in oil spill areas, in which an increased incidence of mangrove mutation has been reported (Klekowski et al. 1994). Lighter oils are generally considered more toxic to mangroves than are heavier oils

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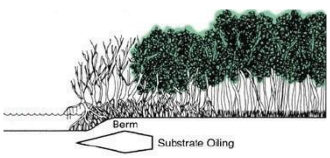
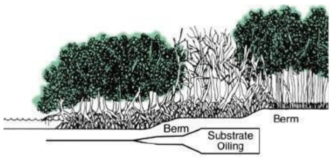
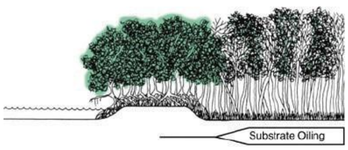
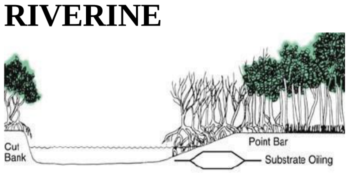
Table 1. Mangroves can experience four types of impacts when polluted with oil. (Adapted from Getter et al., 1981)

Impact	What Happens?	What is Affected?
OUTER FRINGE 	Oil is trapped on and in front of a high berm at the outer edge of the forest.	Most of the oil collects in and impacts a small area, resulting in defoliation or death of shoreline mangroves and leading to shoreline erosion.
INNER FRINGE 	Oil is pushed into the mangrove forest and deposited on the inner berm.	The vegetation in the area of highest oiling is stressed or dies.
INNER BASIN 	Oil is carried over the coastal berm or through tidal flats into a sheltered mangrove basin.	Oil can be spread over a wide area and damage can be more scattered.
RIVERINE 	Oil accumulates on gently sloping sand bars, with the potential for penetration into the porous soils.	With both oiling of the roots and in the soils, damage can be severe.

Oil enters the mangrove ecosystems through currents and waves. Once in the area, oil frequently gathers, covers the plants, and seeps into the ground. In a mangrove forest, water travels slowly, which slows down natural removal. The physical environment, including land features like berms and exposure to waves, affects the location and duration of oil spills, according to observations made after previous incidents. (Table 1).

Mangroves may be exposed to oil and experience both acute and chronic effects. They could exhibit oiling within the first two weeks following a spill, but it might take weeks, months, or even a year for any evidence of oiling to surface. Mangrove branches may die or lose their leaves, they may stunt or distort when oiling occurs.

Mangrove seedlings may also wither or deteriorate upon exposure to oil (Lewis, 2005). Following oiling, the quantity, distribution, or even death of plants and animals inside the mangrove forest are possible. Defoliation may result from oil exposure. The forest floor becomes more light-filled as leaves fall, raising the temperature and salinity (Clark et al., 1997). These situations may lead to malformations in the leaves, the death of seedlings, or even the death of the tree. Mature, taller trees may go six months or longer without exhibiting any symptoms before dying.

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Table 2. Generalized responses of mangrove forests to oil spills. From Lewis (1983).

STAGE	OBSERVED IMPACT
Acute	
0 - 15 days	Deaths of birds, fish, invertebrates
15 - 30 days	Defoliation and death of small (<1 m) mangroves Loss of aerial root community
Chronic	
30 days - 1 year	Defoliation and death of medium (<3 m) mangroves Tissue damage to aerial roots
1 year – 5 years	Death of larger (>3 m) mangroves Loss of aerial roots Regrowth of roots (sometimes deformed) Recolonization of oiled areas by new seedlings
1 year – 10 years?	Reduction in litter fall Reduced reproduction Reduced seedling survival Death or reduced growth of recolonizing trees? Increased insect damage?
10 – 50 years?	Complete recovery

Oil can have varying impacts on mangrove forests, depending on factors such as the type of oil (Table 2), the volume of the spill, and the proximity of the spill to the forest (an, 2016). One of the key factors that determine the impact of an oil spill on mangrove forests is the type of oil involved (Norman et al., 1997). Different types of oil have varying levels of toxicity and persistence in the environment, which can greatly influence the extent of damage to the mangroves. For example, light crude oil tends to evaporate more quickly and is less viscous than heavy crude oil, making it less likely to coat and suffocate mangrove roots (Mitra & Zaman, 2020). Additionally, the volume of the spill plays a significant role in determining the severity of the impact. Larger spills are more likely to overwhelm the natural resilience of mangrove ecosystems, leading to widespread damage and long-term consequences (Little et al. 2021).). Finally, the proximity of the spill to the forest can also affect the degree of harm inflicted. Spills that occur directly within the boundaries of a mangrove forest are likely to have

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a more immediate and severe impact compared to those that are further away (Tasrina et al., 2021)

Implication For Climate Change

The implications of mangrove degradation on climate change include the loss of coastal protection, increased vulnerability to storm surges, and sea-level rise. (Blankespoor et al. 2017; Ellison, 2015). The pollution and degradation of blue carbon ecosystems in the Niger Delta region by oil-based anthropogenic and natural factors impairs their natural services, undermines the values of the ecosystems for communities (Weaver et al. (2024), and also renders many riverine communities extremely vulnerable to the negative impacts of climate change. These impacts include environmental, economic, and health hazards. They include increasing flooding in both upland and riverine communities, leading to the destruction of properties worth hundreds of millions of dollars; the spreading of various diseases such as malaria, typhoid, and topical skin diseases due to the rampant movement of vectors; and human consumption of polluted and contaminated water, leading to cancer and a short life span.

Others are biodiversity loss (depletion of fish nurseries, loss of vegetation, and endangered animal species), desertification, coastal erosions, storm surges, and loss of arable agricultural lands, leading to poverty and violence in community conflicts due to competition for natural resources. (Giller et al. 2008; Ploeg, 2011). Climate change exacerbates these environmental issues, making them more frequent and severe. Rising global temperatures contribute to the spread of diseases and the destruction of ecosystems. In addition, extreme weather events like hurricanes and droughts further strain communities that are already struggling to survive. Without immediate action to mitigate climate change, these environmental challenges will only continue to worsen, leading to more widespread suffering and hardship for people around the world.

Mangrove degradation exacerbates these impacts by reducing the natural buffer that mangroves provide against erosion and flooding. Without the protective barrier of mangroves, coastal communities are left more exposed to the destructive forces of extreme weather events (Ihinegbu et al. 2023) . In addition, the loss of mangroves contributes to the decline of important fish habitats and nurseries, further threatening the livelihoods of coastal communities that rely on these ecosystems for food and income (Alongi, 2008). The degradation of mangroves also leads to a decrease in carbon sequestration, as healthy mangrove forests are highly effective at storing carbon dioxide from the atmosphere (Barbier, 2016). These environmental impacts not only harm the ecosystem but also have detrimental effects on human health and well-being. (Ferreira & Venter, 2016). The spread of diseases and consumption of contaminated water led to a decrease in productivity and an increase in healthcare costs for affected communities (Moe & Rheingans, 2006). Additionally, the loss of biodiversity and arable land further exacerbates poverty and food insecurity, creating a cycle of environmental degradation and social unrest (Tiziano, 2016). These environmental impacts not only harm the ecosystem but also have detrimental effects on human health and well-being. (Ferreira & Venter, 2016).

The spread of diseases and consumption of contaminated water leads to a decrease in productivity and an increase in healthcare costs for affected communities (Moe & Rheingans, 2006). Additionally, the loss of biodiversity and arable land further exacerbates poverty and food insecurity, creating a cycle of environmental degradation and social unrest (Tiziano, 2016)

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It is crucial that urgent action be taken to address these issues and promote sustainable ractices to protect both the environment and human livelihoods.

CONCLUSION

Non-standardized artisanal refineries in the Niger Delta region are significant sources of pollution, leading to mangrove destruction. In this review, an attempt was made to examine the phenomenon of the ecological implications of non-standardized refineries on mangrove in the Niger Delta. This study emphasized the environmental issues, risks, and ecological significance of mangroves in the Niger Delta. The study revealed that mangroves play a crucial role in protecting coastal areas from erosion and storms, as well as providing a habitat for diverse plant and animal species, and that they are threatened by the operation of non-standardized oil refineries in the creeks of the Niger Delta region of Nigeria.

RECOMMENDATIONS

Through the implementation of sustainable conservation strategies, the long-term health and resilience of mangrove ecosystems can be safeguarded. Preserving and restoring mangrove forests in the Niger Delta region is crucial for the well-being of both present and future generations, requiring coordinated efforts. This can be achieved through a combination of community engagement, scientific research, and policy implementation. By involving local communities in conservation efforts, we can ensure that their traditional knowledge and practices are incorporated into restoration plans. Furthermore, conducting ongoing research on mangrove ecosystems is crucial for understanding their unique characteristics and effective management and protection. Policymakers should also prioritize the protection of mangrove forests by enacting legislation that promotes sustainable land use practices and discourages destructive activities such as deforestation and pollution.

Furthermore, the federal government of Nigeria should develop a long-term plan for the conversion of non-standardized refineries to standardized modular refineries. This transition will provide a sustainable and efficient method for processing crude oil, leading to reduced emissions and accidents. Upgrading makeshift refineries in the Niger Delta to meet standardized specifications would ensure quality control and environmental compliance. This transition streamlines operations, cuts cost, enhances production capacity flexibility, and safeguards mangrove ecosystems from degradation. Adopting this approach would demonstrate the commitment of the Federal Government of Nigeria to environmental sustainability and pave the way for a more resilient and environmentally friendly new dawn in the oil and gas industry.

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