A RESEARCH FRAMEWORK TO ASSESS THE IMPACTS OF OIL POLLUTION ON NIGER DELTA ECOSYSTEMS

by

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A Research Framework to Assess the Impacts of Oil Pollution on Niger Delta Ecosystems

Submitted by	Abiodun Abimbola Ilemobayo	in partial fulfillment of the requirements for
the degree of	Master of Science	
in	Forestry	

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Abstract

Nigeria's oil-rich Niger Delta region is the country's lifeblood, contributing 85% of the national economy. Paradoxically, the region remains heavily dependent on fishing and farming as essential means of survival. However, its entire ecosystem, which supports these services, is under severe threat due to relentless crude oil exploration. This study uses the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) systematic literature review protocol to design a framework. This framework depicts the various impacts of oil spills on the Niger Delta ecosystems, particularly forest ecosystems, rural livelihoods and food security. The review process was completed in four stages: data acquisition, document screening, qualitative data extraction, and results presentation. First, data acquisition involved searching relevant articles from various sources, including Google Scholar, Web of Science, Elsevier Scopus, PubMed Central and relevant grey literature. Exclusion criteria were used to remove documents that were not relevant for this research. The included article used a reproducible method, reported relevant outcomes, and focused on oil pollution in the Niger Delta of Nigeria. One hundred and fifteen (115) full-text publications were eventually obtained for data analysis using NVIVO software.

The result analysis stage involved the coding, identification, and interpretation of themes obtained by querying the compendium of information obtained. Three layers that bear different components and subcomponents that are affected by crude oil were identified. The first layer (Layer 1) consists of humans, *Aquatic Environment*, and *Terrestrial Environment*. The authors discussed the impacts of oil pollution on the *Humans* component, with a percentage probability of 78% greater than both *Aquatic Environment* and *Terrestrial Environment* components. Layer 2 consists of six factors that are affected by oil spills. Of these factors, *Human Health and Mortality Rate* and *Forest Habitat and Ecosystem Services* share equal significance. However, the impact on Water was scarcely discussed by authors, as it accounts for just 39.1% probability. Layer 3

consists of sixteen factors (16). Some of the most discussed factors by authors are *Aquatic Vertebrates, Vegetation, and Consumption patterns*. In contrast, some of the least discussed factors are *Human Displacement*, *Conflicts, Aquatic Invertebrates*, *Human Exposure*, and *Food Quality*.

Lay Summary

Nigeria's economy depends on the oil-rich Niger Delta region. Despite the immense contribution from oil companies in the region, its inhabitants still reply on agriculture as a primary means of sustenance. Unfortunately, the region's agricultural resources are under serious threat from oil exploration. Hence, this research investigates the impacts of oil pollution in the region using the PRISMA protocol. The protocol was divided into data extraction, document screening, qualitative data extraction and results analysis phases. Qualitative data extraction was done with the help of NVivo software, while the data obtained were analysed. It was observed that impacts on the Humans were mostly considered by authors, while fewer authors discussed impacts on Aquatic Environment and Terrestrial Environment. Additionally, the livelihood system of the Niger Delta people was impacted significantly. The research culminated in the creation of a Niger Delta oil-impact framework that could serve as a roadmap for future researchers.

Preface

This research was born out of the need to establish a research framework to enable environmental scientists and environmentalists alike to accurately measure the various impacts of oil pollution in the Niger Delta region of Nigeria. Although the literature is already awash with interesting research in this domain, the developed framework will certainly serve as a better guide to making objective judgements about the impacts of oil pollution in the region. Three major ecosystem components as they relate to the region were considered: namely Humans, Aquatic Environment and Terrestrial Environment. I designed the research methodology and objectives with the inclusion of consequential inputs and suggestions by my supervisor, Prof. Terry Sunderland and members of the supervisory committee, Prof. Jeanine Rhemtulla and Prof. Robert Kozak. Prof. Terry Sunderland led the conceptualization of the research and with his advice, I used PRISMA flow method of systematic review for my method and developing the research framework.

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List of Acronyms

CIFOR – Center for International Forestry Research

DDI – Dietary Daily Intake

DNA – Deoxyribonucleic Acid

ECR – Excess Cancer Risk

FAO – Food and Agricultural Organisation

GHG – Greenhouse Gases

HI – Hazard Index

HMW – High Molecular Weight

IUCN – International Union for Conservation of Nature

LMW – Low Molecular Weight

PAHs – Polycyclic Aromatic Hydrocarbons

PHE – Phenanthrene

PHEQ – Phenanthrenequinone

TEQ – Toxic Equivalent

THQ – Target Hazard Index

UN – United Nations

UNDP – United Nations Development Programme

USEPA – United States Environmental Protection Agency

WHO – World Health Organization

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Dedication

To my dearest mum,

Dr. (Mrs.) Olufunke Ilemobayo

for all the sacrifices you have made for me

Chapter 1 : Introduction

1.1 Background

Our global economy has a heavy reliance on fossil fuels. These fossil fuels are not just for energy generation but also for transportation, agriculture, building construction and industrial manufacturing. However, the reliance on fossil fuels has led to the establishment of multinational crude oil processing companies and their servicing counterparts (Pickl, 2019). There are over 200 oil and gas companies worldwide, and a growing number of subsidiaries and other smaller oil servicing companies (Muspratt, 2019). The supermajors in the oil and gas industry include Chevron, Total, Exxon Mobil, and Shell. These conglomerate oil firms have become household names in the global economy (Satyakti, 2017). Without a doubt, these companies have contributed immensely to the global economy. However, the results of their industrial activities have accelerated climate change and environmental degradation through oil pollution and GHG emissions. For example, around 45% of the world's greenhouse gas (GHG) emissions, which cause climate change, are attributed to energy supply and industrial activities (Yihui & Sokhi, 2008). About 58% of these GHG are made up of carbon dioxide (CO_2) released from the combustion of fossil fuels (Yihui & Sokhi, 2008).

Oil exploration and extraction activities by oil and gas companies have inadvertently contributed to the release of harmful hydrocarbons into our environment through accidental spills from oil rigs and offshore platforms during pipeline installation, dredging, and oil transportation by tankers and ships (Zhang et al., 2019). The two major primary avenues through which the oil and gas industry degrades our environment and upset our natural ecosystem are oil spills and gas flaring, and their effects have been felt in oil-producing communities where there is an increased frequency of acid rain which contributes to global climate change (Amadi, 2014). So, the overall incidence of oil spillage has caused air, land, and water pollution, which threatens the well-being of rural inhabitants. Accidental oil spillage is inevitable in an oil-producing environment. As a result, the consequences of oil spillage is soil degradation resulting from the destruction of soil microorganisms, causing many untold hardships to a growing population. These events are particularly evident in the Niger Delta region of Nigeria.

Despite the impacts of oil spillage in the Niger Delta, the accrued benefits of hosting multinational oil companies in the Niger Delta communities cannot be overlooked. The presence of these companies has provided jobs to some Niger Deltans. For example, according to SPDC (n.d), 66% of the 4,500 Nigerians employed in SPDC are indigenous Niger Deltans. This implies that only 2,970 Niger Deltans are oil workers out of the 30 million plus population of the region. The remaining Niger Deltans who are not gainfully employed in these companies engage in other livelihood activities ranging from farming and agricultural extension services to other jobs. For instance, in a survey undertaken by Ikechi et al. (2014), 246,909 responses collated were made up of farmers and agricultural extension workers. In the face of these benefits, statistics from Nigerian National Petroleum Corporation (NNPC) have indicated that yearly, 300 spills occurred in the Niger Delta with an estimated 2,300 cubic metres of oil spilled into the environment between 1975 and 1995 (Osuagwu & Olaifa, 2018). In contrast, records from the World Bank have debunked the figures provided by NNPC because their archive showed that the annual spills in the Niger Delta were more than ten times those reported by NNPC. The frequency of oil spills has, in recent times, increased exponentially. In fact, Akinwumiju et al. (2020) showed that between 2006 and 2019 about 7,943 oil spill incidents have occurred in the Niger Delta. As a result, farmers and agricultural extension workers are the worst hit in the event of an oil spill. Hence, it is evident that there is a nexus between oil production and Niger Delta rural livelihoods. However, at the moment, there is no universal framework that accurately and systematically measures or shows the multifaceted impacts of crude oil pollution in the Niger Delta. Establishing a framework in this context will provide researchers with enough information to prioritise their research interest in the areas where it is most needed. It will also assist all stakeholders in the Niger delta in developing a better strategy to address the impacts of oil spills.

1.2 Research Question

How does oil pollution in the Niger Delta affect forest ecosystems and rural livelihoods?

1.3 Research Objectives

The main objective of this research is to develop a framework for accurately depicting the impacts of oil pollution in the Niger Delta.

1.4 The Current Challenges in Niger Delta Nigeria

The Niger Delta of Nigeria covers an area exceeding 29,900 km^2 with a population of over 30 million people (Kuenzer et al., 2014). It is rich in crude oil and is also a biodiversity hotspot (Onu, 2003). The region's fertile ecosystem supports resources such as oil palm, coconut, cocoa, rubber, and timber (Watson, 2014; Arugu, 2015; Yekeen, 2019). Ironically, the region, which now contributes 85% of the national revenue via crude oil exports, remains heavily dependent on agriculture as an essential means of survival (Ekanem & Nwachukwu, 2015). Oil exploitation has increased local degradation through dredging, oil spill and gas flaring, resulting in increased biodiversity loss, soil infertility, and forest loss in the Niger Delta (Akinro et al., 2008; Kadafa, 2012a). The high exploitation and extraction rate of crude oil results from the collaboration between the Federal Government of Nigeria and the leadership of the Niger Delta communities. The collaboration has enabled multinational companies to establish mining and drilling sites for crude oil and natural gas in this region (Figure 1.1). Unfortunately, in mining these resources, around 40 million litres of the extracted crude oil accidentally discharges into the aquatic and terrestrial environment surrounding these mining sites, mostly through sabotage and a culture of poor maintenance (Ratcliffe, 2019). Consequently, the Niger Delta ecosystems and their accompanying habitats have been severely affected (Eluozo, 2018). For example, Obida et al. (2018) showed that 29% of the 565,000 people in the surrounding communities (about 2% of the Niger Delta population), were poisoned through the ingestion and consumption of oil-polluted drinking water and agricultural produce, respectively. Osuagwu & Olaifa (2018) carried out a study on the effects of oil spills on fish production in the Niger Delta and report that oil pollution jeopardizes fish hatcheries in coastal waters and adulterates the flesh of commercial fish, making it inedible.

Production-level oil exploration requires a large expanse of lands, which means that other activities will be overridden. Thus, oil exploration in the Niger Delta is mostly carried out via exploratory wells. There are 6,400 oil wells that are interconnected to oil pipelines with networks (Figure 1.1) that surround the landmass of the regions and cover 1,143km across the Niger Delta region (Akinwumiju et al., 2020). The quantity of oil wells and extent of pipeline networks in the region has intensified crude oil exploration in the region, resulting in the contamination of soil, which is indispensable for healthy plant growth (Izah et al., 2018; Enuoh & Ogogo, 2018). Furthermore, low soil fertility has led to downward trending agricultural yields, which has resulted in reduced food productivity. This decrease in agricultural productivity has also led to an increased incidence of poverty within the Niger Delta (Akpokodje & Salau, 2015). In the context of environmental degradation, the overall impacts of oil spills have reduced access to safe and nutritious food suitable for the region's populace's dietary needs. The early harvest of crop yields to avoid excessive loss from oil spills is an added consequence of environmental degradation within the Niger Delta. Further destruction of the populace's livelihood opportunities leads to loss of income and increased antisocial activities, such as kidnapping, robbery and oil pipeline sabotage (Nwachukwu & Mbachu, 2018). The proliferation of these activities is a result of the absence of fertile land in the upland Niger Delta and pollution of water bodies in the coastal areas, which greatly impact the livelihoods of the local communities.

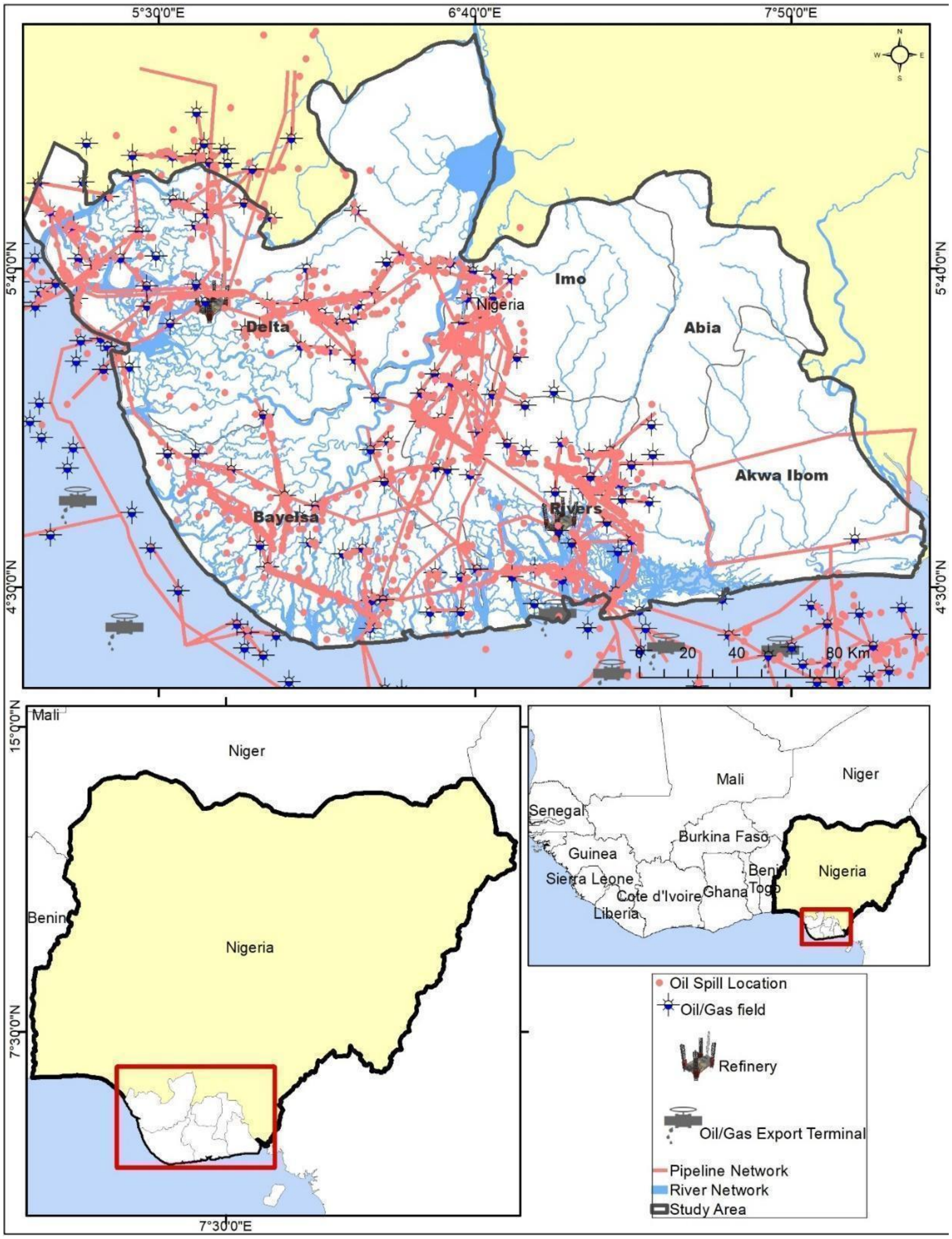

Figure 1.1: Map of Niger Delta with all crude oil production and transmission activities [data source: Fischer et al. (2008)]

1.5 The vegetation Type in Niger Delta, Nigeria

The vegetation of the Niger Delta is richly bio-diversified and accounts for various ecosystems, including swamp forest, lowland rainforest, and mangrove forest (Ayalande, 2014; Igu & Marchant, 2017). The Niger Delta is not only naturally endowed with mineral resources such as crude oil but also harbours a high level of species biodiversity in terms of tree and animal species but also varieties of tree and animal species (Seiyaboh & Izah, 2017). The Nigerian wildlife ecosystem comprises about 7,895 plant species (including 338 families and 2,215 genera), over 22,000 animal species (vertebrates and invertebrates, including 20,000 insects, 100 birds, 1,000 fishes, 247 mammals, and 123 reptiles), and 1,489 microorganisms (Osawaru et al., 2013; Izah, 2018). Specifically, certain sites in the Niger Delta region of Nigeria share this multiplicity of biodiversity (Izah, 2018). For example, in Wilberforce Island, Bayelsa State, there are 45 mammals (and 21 families), 78 avian fauna (belonging to 27 families) and over 56 plant species (Izah, 2018). Another example is seen in the Nun River forest of Bayelsa state, where there are 36 mammals (belonging to 18 families) and 18 reptiles (belonging to 12 families), and 67 avian fauna belonging to 25 families (Izah, 2018). A unique species, West African lucinid bivalve *Keletistes rhizoecus*, also exists in the Niger Delta (Zabbey et al., 2010).

Summarily, the Niger Delta is rich in biodiversity, essentially because of the different ecological zones it supports and the assemblage of varieties of wildlife and different species of organisms (Ayanlade & Drake, 2015). Ezenwaka & Graves (2014) highlighted some benefits of the Niger Delta ecosystem, which are provisioning of consumables such as food and water; regulating services such as erosion and flood control, climate regulation and water purification; cultural services that rather promotes the practice of few recreational activities, educational and spiritual benefits; and supporting services such as soil formation, biomass production, habitat provision and water cycling. The local people of the Niger Delta depend heavily on the provisioning services (consumptive and extractive benefits) of the Niger Delta ecosystem for basic livelihood requirements and wellbeing (Ezenwaka & Graves, 2014). For instance, the ecosystem provides a wide variety of timber and non-timber forest products including aquatic resources, whose byproducts are further used for medicine, food, and utensils (Ezenwaka & Graves, 2014).

Essentially, there are three main forest types, namely mangrove forest, freshwater swamp forest and lowland rainforest in the Niger Delta, Nigeria. Mangrove forests are found in the intertidal zone of tropical regions in the world and it is richly biodiverse and serves as an interface between the land and sea (Gajula et al., 2020; Kumari et al., 2020). Freshwater swamp forests are forests that are usually inundated with freshwater. They are rich in minerals and occur seasonally or permanently in tropical, subtropical and temperate regions. Usually, they are found at the lower parts of water bodies (Bada, 2018). Lowland tropical rainforests are one of the most complex ecological zones with evergreen tree species having a great height of about 60m. The lowland forest is also characterised by flourishing trees with dense canopies (Glime, 2019). In light of the Niger Delta, these forest types will be discussed considerably in subsequent subsections.

1.5.1 Mangrove Forest

In the Niger Delta, mangroves are the most predominant forest ecosystem and accounts for around 50% of the total mangroves in West Africa with high levels of species diversity (14 taxa of macrofauna with over 60 species), although not comparable with those of terrestrial forests (Carugati et al., 2018; Ewah-Oboho et al., 2005, U.S Geological Survey, 2013). This forest ecosystem provides a diverse range of benefits, including conservation of biodiversity, soil and water, as well as timber production (Igu, & Marchant, 2016; Igu & Marchant, 2018). These ecological services, in turn, improve living conditions for local inhabitants. The mangrove habitat also provides refuge for varieties of fish species and food in the form of fish and shellfish harvested by local communities and, most importantly, food chain support (Onyena & Sam, 2020). Organisms such as zooplankton (e.g., Cyclopoida, Ostracoda, and Cladocera) which are mainly found floating in water, is an important food source for many aquatic organism (Ikhuoriah et al., 2015) and a significant proportion of the foods eaten in the Niger Delta comes from the aquatic environment (Etuk et al., 2020). Other benefits of the mangrove forest ecosystem are the provision of wood fuel for both cooking and drying fish.

The tree trunks protruding out of the muddy soil is one of the significant characteristics of mangroves (IUCN, n.d.). These trunks harbour a host of other species such as fish and crustaceans (IUCN, n.d.). The trees are usually 40 meters high or as shrubs below the high-water level of spring tides (Ohimain, 2016). This vegetation formation has a remarkable ability to sequester carbon dioxide more effectively than other terrestrial ecosystems (Huxham et al., 2018; Donato et al., 2011, Alongi, 2014). Unfortunately, the mangrove environment has been severely affected by oil pollution. Dredging for oil exploratory activities in the Niger Delta disturbed mangroves, providing an opportunity for colonization by Nypa palm weeds (Nababa et al., 2020; Feka & Ajonina, 2011). This palm was introduced to Calabar in the early 1900s and has since spread throughout West Africa (Sunderland and Morakinyo, 2002). Figure 1.2 illustrates the changes in the mangrove rainforest over 33 years and the progression in the loss of Niger Delta mangrove forest can be visibly observed. From the figure, in the year 1987, Bayelsa state was densely occupied by the mangrove rainforest and terrestrial forests, but 13 years later, the loss of these ecosystems is noticeable. Worse still, in 2020, the mangrove forest became further degraded and replaced with sparse vegetation. Terrestrial forests are now gradually taken over by local settlements and mangroves have now been replaced with bare swamps. Oil exploration activities, invasion of the Nypa palm species (*Nypa fruticans*), exploration of the mangrove for fuelwood, agriculture, urbanisation is some of the important drivers of mangrove forest change in the Niger

Delta (Nababa et al., 2020; Feka & Ajonina, 2011). Around 4,000,000 cubic metres of Mangrove woods are harvested in Nigeria. In the same vein, coastal Nigeria is also a host to 85% of all industries which has led to a population explosion in this region (Ibe and Awosika, 1991). However, oil exploration activities and urbanisation are the major drivers of this change (Kadafa, 2012a). Particularly, oil exploration has, over a period of 26 years (1980-2006), caused the loss of approximately 2568ha of mangrove forest and this number has gone up in recent times (Feka & Ajonina, 2011).

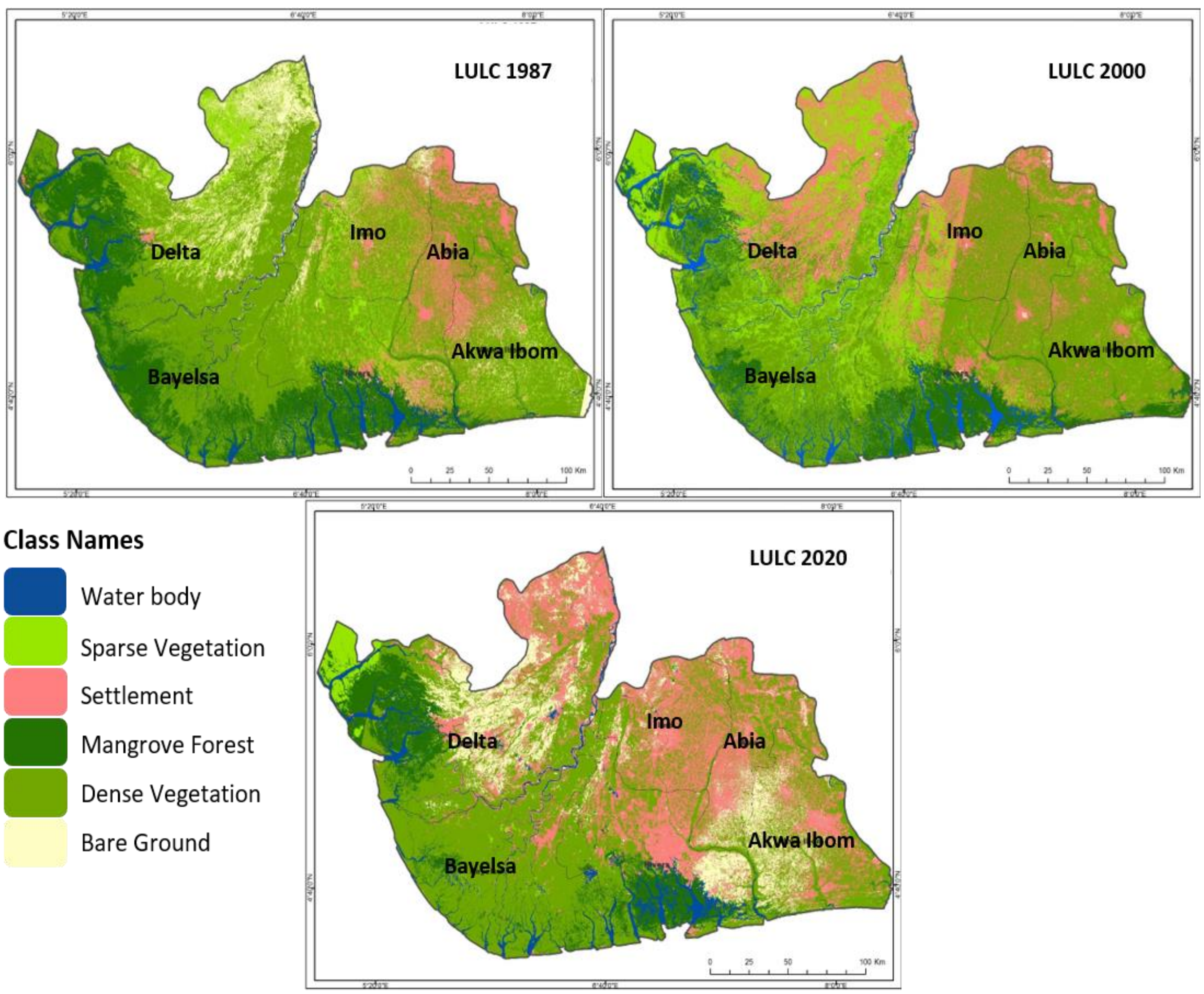

Figure 1.2: Changes in land use cover for major Niger Delta states [data source: Fischer et al. (2008)]

1.5.2 Freshwater Swamp Forests

The freshwater swamp forest ecosystem is defined globally by its unique physical and chemical processes, which differentiate them from other forest ecosystems (Igu & Marchant, 2016). It covers about 17,000 km^2 which is about half of the entire Delta region (Igu & Marchant, 2017). The freshwater swamp forest ecosystem plays a vital role in regulating the climate, sequestering carbon, controlling flooding and purifying water (Omokhua & Koyejo, 2008). They are usually associated with streams and rivers that often flow into the surrounding sea. Niger Delta's freshwater ecosystem lies between the lowland rainforest and mangrove swamp forest, providing a transition zone between them whilst serving as a migratory boundary for both fauna and flora (Ibimilua, 2013; Igu & Marchant, 2017). It is also a supplier of timber and forest products to the local population (UNDP, 2006). The ecosystem is home to aquatic species such as crayfish, prawn and crocodile. The soils of freshwater swamp forests are usually fertile due to the migration of rich mineral sediments transported from the sea to the land during flooding. This helps replenish the soil nutrients as well as providing the ability to recover from natural ecosystem disturbances (Thomas & Baltzer, 2002). Freshwater swamp forests are occasionally classified into seasonally flooded swamp forests and permanently flooded swamp forests. Freshwater tree species usually exceed 30m in height (Omokhua & Koyejo, 2008). Despite the potential of regulating coastal water flow and eliminating sediment and pollutants from moving water, evidence suggests that the ecosystem is in jeopardy. The devastation of floodwaters caused by rising temperatures and climate change resulting from gas flaring (oil exploration activities) and deforestation could lead to the dwindling of its biodiversity (Omokhua & Koyejo, 2008; Agbagwa & Ekeke, 2011). This claim has been corroborated by Igu (2017) who revealed that the freshwater swamp forests now have a low species biodiversity due to a reduction in the number of species and loss of species habitats which can be closely linked to industrialization and urbanization. Hence, adequate conservation measures have to be institutionalized across landscapes to preserve the already few species in the freshwater swamp forest ecosystem.

1.5.3 Lowland Rain Forest

The Nigerian Lowland Forest ecosystem is restricted to a narrow band along the southwest Nigerian coast, stretching from east of Benin to west of the Niger Delta. Mangrove and swamp forests separate the lowland forest. In the North, the lowland tropical rainforest gradually transitions into the Guinea Forest-Savanna Mosaic (WWF, n.d.). The lowland rainforest is one of the most complex ecological zones in the Niger Delta region. Local medicines, wild foods and timber products are all derived from this vegetation. Some commonly found species are *Terminalia ivorensis* (used in traditional medicine as a diuretic and for the management of renal failure), *Triplochiton scleroxylon* (used as a rich protein food and providing shades for cocoa plantations) and *Terminalia superba* (used for the treatment of a variety of disease including but not limited to female infertility, diabetes mellitus and abdominal pains) (Ayanlade, 2014; Moomin et al., 2020, Fern, 2014; Kougnimon et al., 2018). Endemism is low in the Niger Delta region, despite the sharp divide between the Niger River and Dahomey Gap in the Benin Republic compared to other lowland forest ecosystems in West and Central Africa (WWF, n.d.). Certain animal species, such as the endemic Niger Delta red colobus (*Piliocolobus epieni)*, are already being threatened by forest loss.

In recent times, the biodiversity of the lowland rainforest has declined due to gas flaring, uncontrolled oil spill, loss of forest and urbanization. The constant release of non-biodegradable industrial wastes from crude oil processing companies has caused enormous environmental damage and loss of fauna and flora habitats (Izah et al., 2018).

1.6 Current State of Niger Delta's Livelihood Systems

Livelihood systems are trades, businesses or profitable activities that people are involved in which ensure their survival (CIFOR, n.d). It could also mean the process of acquiring the necessities of life (i.e., food, water, shelter, and clothing). Generic examples of livelihood systems are farming, fishing, commerce, and tourism. According to the 2006 census, the Niger Delta population density sits around 30 million and for every square kilometer, there are 256 people (Fund for Peace, 2016). The majority of this population engage in agricultural practices, such as fishing and farming, which serves as their major livelihood system, with 2,604 fisheries households which is incomparable with the number of farmers in the region (Abah, 2013). The region has a pluralistic land tenure system in which multiple households could own a particular piece of land (Hennings, 2021). Subsistence farmers who live in the upland areas of the region rely on fertile arable land for growing crops. Marketing their farm produce to support their families comes immediately after harvesting. Similarly, in the coastal areas, fishers usually wade through neighbouring water bodies devoid of crude oil pollution to catch fish for subsistence use and also for sale.

However, the sustainability of the region's livelihood system is not guaranteed. On several occasions, the Federal Government of Nigeria had allocated suitable agricultural lands to the oil industry for the mining of crude oil (Albert et al., 2017). Hence, community members have lost their rights to occupy those lands because such lands have no legal tenure which eventually lead to loss of livelihoods (Baba et al., 2020). The fallout from mining activities in the Niger Delta pollute lands and damage the soil structure, making the environment unsuitable for farming even after mining operations are suspended for some time. For instance, the 20 years plus Shell Petroleum Company oil exploration in Ogoni Land, Niger Delta, has left enormous carbon footprints and deposits of hydrocarbons in the environment, which has destroyed both the agricultural sector and manpower in the community (Lindén & Pålsson, 2013). This has worsened the state of the already moribund livelihood systems and led to revenue loss to both the Local Government and Federal Government (Ijekeye, 2019). Hence, the overall impact of the appropriation of agricultural lands to oil companies trickles down to even the Federal Governments of Nigeria and the associated Niger Delta communities. As a result, rural dwellers in the Niger Delta now struggle to access basic human needs such as clothing, food and shelter because their lands, which once provided means of survival, are now unsuitable for agricultural practices. This situation becomes even more difficult when peasant farmers have to grapple with degraded lands, psychologically impacting them. The health risks associated with this worrisome situation are discussed in Chapter 3 of this thesis.

Chapter 2 : Methodology

2.1 Methodological Approach

This study investigated the effects of oil pollution on forest ecosystems, food security, and the livelihood of residents in Nigeria's Niger Delta. A systematic review using the PRISMA protocol was conducted. The PRISMA protocol, which stands for Preferred Reporting Items for Systematic Reviews and Meta-Analysis, is an evidence-based minimum set of items for reporting systematic reviews and meta-analysis in a transparent and thorough manner (Page et al., 2020; Foli et al., 2015). In this work, I conducted the systematic review in four stages: Data Acquisition, Data/Document Screening, Qualitative Data Extraction and Results Analysis (Figure 2.1).

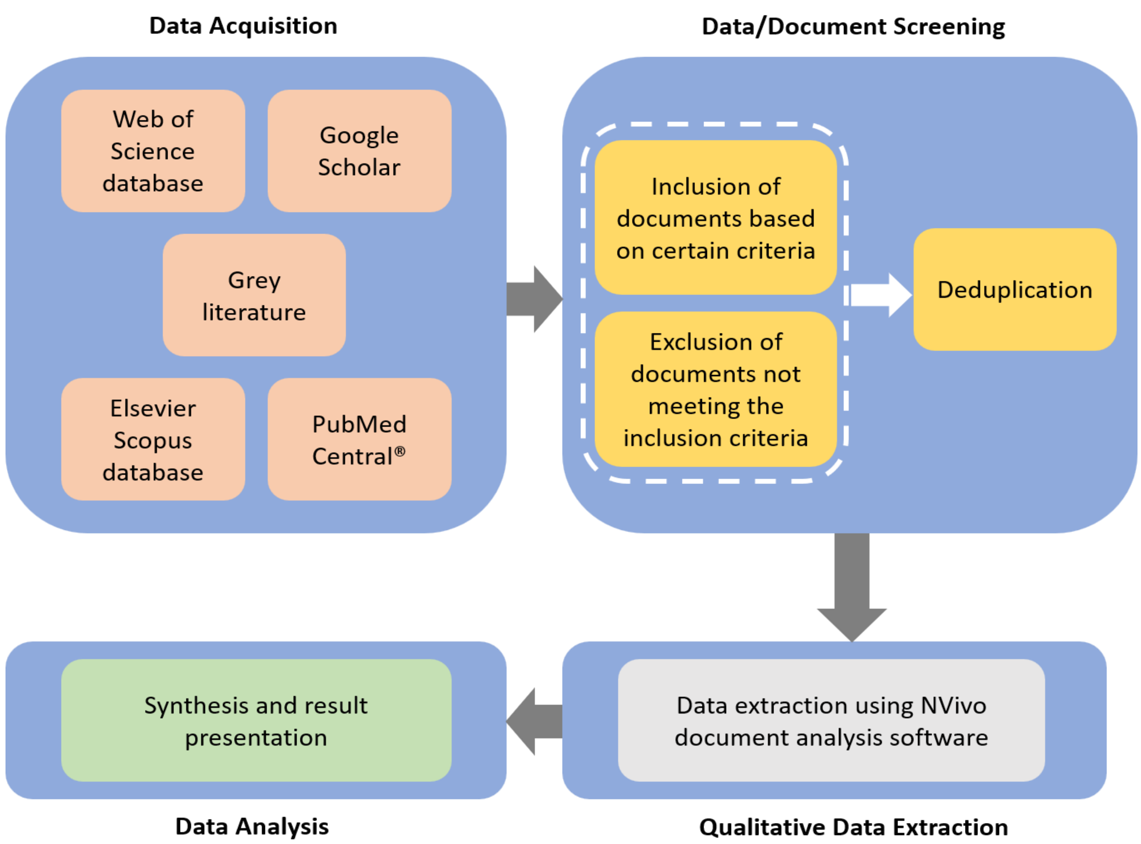

Figure 2.1: Stages of the systematic review

2.1 Data Acquisition

This phase of the research involved the gathering of information from different credible sources. I conducted literature searches on the Web of Science, Google Scholar, Elsevier's Scopus Database, PubMed Central (R) and sources of grey literature, such as Amnesty Nigeria, United Nations Development Programme (UNDP), Food and Agricultural Organisation (FAO), United Nations (UN) and Center for International Forestry Research (CIFOR). There was also some preliminary scoping. Scoping helps reduce unnecessary searching to ensure that studies do not exceed the stipulated timeline for the research.

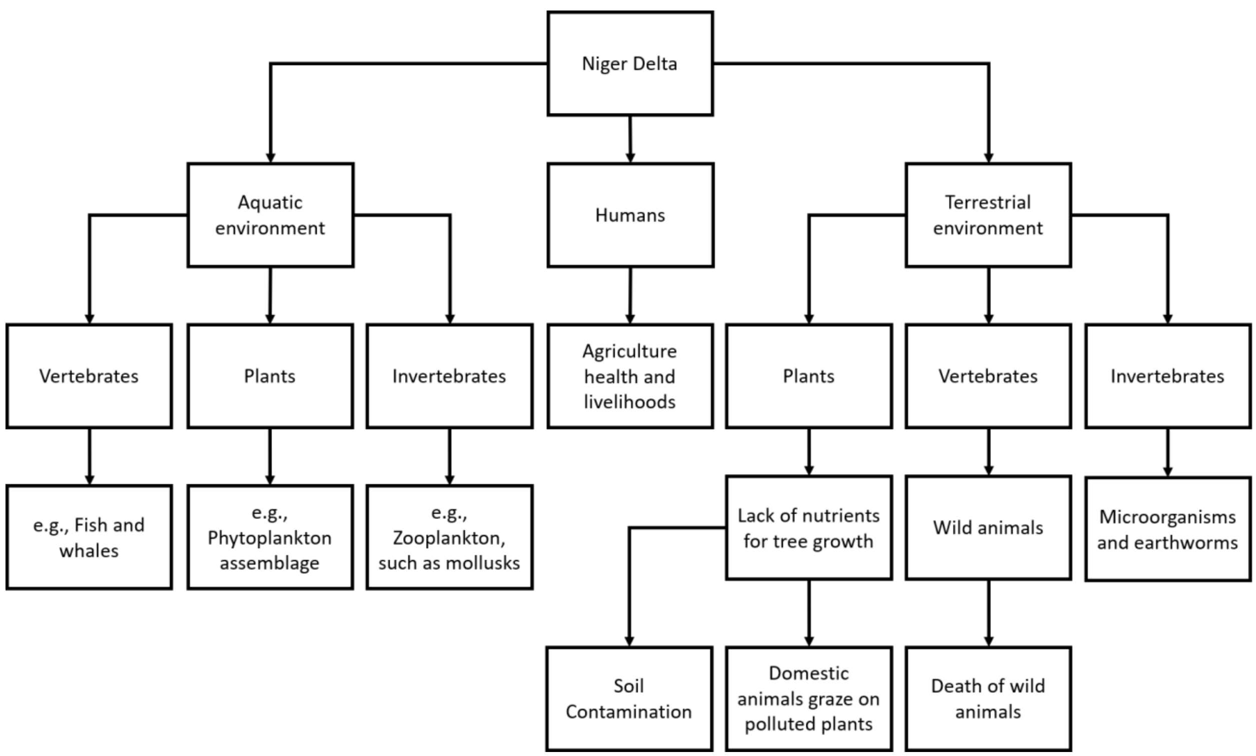

Figure 2.2: Scoping architecture developed from a careful observation of the research title and objective

This scoping strategy was the basis of the search terms queried from the literature resources. The scoping served as a minimalistic blueprint that I followed during the process of acquiring data from relevant sources. The preliminary stage of the data acquisition also involved selecting research keywords. I queried the data sources with the search strings shown in Table 2.1. In Table 2.1, the base search strings were combined to form the derived search strings. Google Scholar, Elsevier's Scopus Database and PubMed Central were queried using these search strings. Using the Google Search Engine, I identified certain gray literature that are in the forefront of research in the environmental issues of Niger Delta, Nigeria and publish periodic reports and issues pertaining to environmental sustainability in the Niger Delta region. These gray literatures were queried using the identified search strings. In using the Google Search Engine, I implemented the logical operators in the derived search string by simply replacing AND and OR with "&" and "+", respectively. A total of 250 citations were acquired after executing the search queries. Table 2.2 shows the respective number of articles retrieved from each queried data source.

Table 2.1: Search strings utilized

SEARCH STRINGS	
Base Search Strings	Derived Search Strings
"Niger Delta"; "Niger Delta Nigeria"; "Niger Delta of Nigeria"; "Biodiversity"; "Biodiversity loss"; "Loss of biodiversity"; "Vertebrates"; "Invertebrates"; "Climate change"; "Gas flaring"; "Forest"; "Forest Ecosystem"; "Vegetation'; "Exploration"; "Oil production"; "Crude oil production"; "Extraction"; "Crude oil extraction"; "Crude oil mining"; "Crude oil"; "Oil"; "Ogoni land"; "Crude oil pollution"; "Oil pollution"; "Oil spill"; "Oil spillage"; "Farming"; "Farmers"; "Fishing"; "Fishers"; "Fishermen"; "Agriculture"; "Human"; "Human health"; "Health"; "Water"; "River"; "Land"	[("Niger Delta" OR "Niger Delta Nigeria" OR "Niger Delta of Nigeria") AND "Biodiversity"]; [("Niger Delta" OR "Niger Delta Nigeria" OR "Niger Delta of Nigeria") AND "Biodiversity loss" OR "Loss of biodiversity"]; [("Niger Delta" OR "Niger Delta Nigeria" OR "Niger Delta of Nigeria") AND "Vertebrates"]; [("Niger Delta" OR "Niger Delta Nigeria" OR "Niger Delta of Nigeria") AND "Invertebrates"]; [("Niger Delta" OR "Niger Delta Nigeria" OR "Niger Delta of Nigeria") AND "Climate change"]; [("Niger Delta" OR "Niger Delta Nigeria" OR "Niger Delta of Nigeria") AND "Gas flaring"]; [("Niger Delta" OR "Niger Delta Nigeria" OR "Niger Delta of Nigeria") AND ("Forest" OR "Forest

	Ecosystem”)]
	[(“Niger Delta” OR “Niger Delta Nigeria” OR “Niger Delta of Nigeria”) AND (“Vegetation”)];
	[(“Niger Delta” OR “Niger Delta Nigeria” OR “Niger Delta of Nigeria”) AND (“Agriculture”)];
	[(“Niger Delta” OR “Niger Delta Nigeria” OR “Niger Delta of Nigeria”) AND (“Exploration” OR “Oil production” OR “Crude oil production”)];
	[(“Niger Delta” OR “Niger Delta Nigeria” OR “Niger Delta of Nigeria”) AND (“Extraction” OR “Crude oil extraction” OR “Crude oil mining)];
	[(“Ogoni land”) AND (“Crude Oil” OR “Oil”)];
	[“Ogoni land” AND (“Crude oil pollution” OR “Oil pollution” OR “Oil spill” OR “Oil spillage”)]
	[(“Niger Delta” OR “Niger Delta Nigeria” OR “Niger Delta of Nigeria”) AND (“Farming” OR “Farmers”)];
	[(“Niger Delta” OR “Niger Delta Nigeria” OR “Niger Delta of Nigeria”) AND (“Fishing” OR “Fishers” OR “Fishermen”)];
	[(“Niger Delta” OR “Niger Delta Nigeria” OR Niger Delta of Nigeria) AND “Ecosystem”];
	[(“Niger Delta” OR “Niger Delta Nigeria” OR Niger Delta of Nigeria) AND “Crude oil”];
	[(“Niger Delta” OR “Niger Delta Nigeria” OR “Niger Delta of Nigeria”) AND (“Oil Spillage” OR “Oil Spill” OR “Crude oil spill” OR “Oil Pollution” OR “Crude oil pollution” OR “Pollution”)];
	[(“Niger Delta” OR “Niger Delta Nigeria” OR “Niger Delta of Nigeria”) AND “Agriculture”];
	[(“Niger Delta” OR “Niger Delta Nigeria” OR “Niger Delta of Nigeria”) AND “Health” OR “Human health”];
	[(“Niger Delta” OR “Niger Delta Nigeria” OR “Niger Delta of Nigeria”) AND “Human”];
	[(“Niger Delta” OR “Niger Delta Nigeria” OR “Niger Delta of Nigeria”) AND “Water” OR “River”];
	[(“Niger Delta” OR “Niger Delta Nigeria” OR “Niger

	Delta of Nigeria") AND "Land]; [("Niger Delta" OR "Niger Delta Nigeria" OR "Niger Delta of Nigeria") AND ("Survival" OR "Livelihood")]; [("Niger Delta" OR "Niger Delta Nigeria" OR "Niger Delta of Nigeria") AND ("Environment" OR "Environmental" OR "Environmental Degradation" OR "Degradation")] [("Niger Delta" OR "Niger Delta Nigeria" OR "Niger Delta of Nigeria") AND ("Habitat")] [("Niger Delta" OR "Niger Delta Nigeria" OR "Niger Delta of Nigeria") AND ("Habitat" OR "Aquatic Habitat")] [("Niger Delta" OR "Niger Delta Nigeria" OR "Niger Delta of Nigeria") AND ("Habitat" OR "Terrestrial Habitat")]

Table 2.2: Number of articles retrieved from each data source

Data Source	**Number of Articles Retrieved**
Google Scholar	105
Elsevier's Scopus Database	56
PubMed Central®	27
Web of Science	28
Gray Literature	34
Total Number of Literature Consulted	250

2.2 Data/Document Screening

This stage involved de-duplicating, and filtering irrelevant documents based on the specific research objective outlined above (Figure 2.3). The titles, abstracts and conclusions of the downloaded articles were evaluated and screened based on their relevance to the research inclusion and exclusion criteria (see below). After implementing the inclusion and exclusion criteria, 110 documents were discarded and 140 were retained and subjected to deduplication.

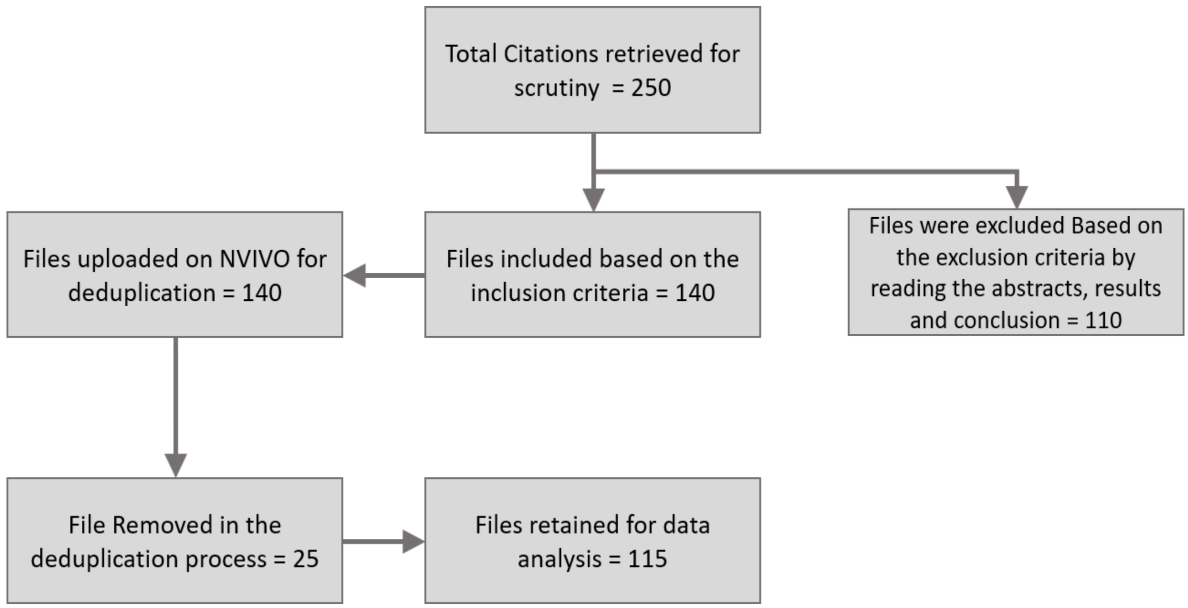

Figure 2.3: Document screening procedure

2.2.1 Inclusion Criteria

Documents were included based on the following criteria of articles that:

- Used reproducible methods and are transparent in their analysis
- Narratively and quantitatively evaluated their research objectives using relevant performance indicators
- Reported relevant outcomes that showed the impacts of oil spillage on the Niger Delta ecosystems of Nigeria
- Only considered the Niger Delta region of Nigeria
- Whose year of publication fall between 2002 and 2021 (this date range was chosen because significant researches were carried out within the periods following increased cases of oil spill)

2.2.2 Exclusion Criteria

The document exclusion criteria that were adopted are articles that:

- The scope was beyond the Niger Delta region of Nigeria
- Involved other forms of pollution other than oil pollution
- Considered only illegal mining of crude oil in the Niger Delta region took cognizance of illegal mines and excluded pollution caused by the significant oil processing companies in the Niger Delta region of Nigeria
- Involved the politics of crude oil exploitation and oil pollution
- Do not clearly communicate the methodologies and analysis used

2.2.3 Deduplication

There are several other available options that could be used to remove duplicate documents (e.g., Ovid multi-file search, MEDLINE, EBSCO and Mendeley (Kwon et al., 2015). However, NVivo was chosen over others because most of them (for instance Ovid) are subscription-based.

In the process of removing duplicate articles, similar titles written by the same author(s) in both a journal and conference proceedings were identified and consequently discarded. Of the 140 subjected to deduplication, 25 duplicate articles were identified and removed, which further reduced the number of articles to 115 for data analysis

2.3 Qualitative Data Extraction

The preliminary stage of data extraction was executed by following procedure:

- In order to draw insights from the literature, a Word Cloud Diagram was generated, which creates a visual of the most frequently used of words in all the articles//literature materials acquired. This was also done with the NVivo document analysis software.

- Adverbs and adjectives (which appear noisy and distracting) that do not seem to contribute to the overall objective of the research were removed. As a result, the research keywords such as "soil", "water", and "environment" were all retained.

2.4 Data Analysis

The final stage of the methodology, which is the Data Analysis stage, involved the analysis of the data acquired from literature resources retrieved. Query results using each keyword component identified, representing both the parent nodes and child nodes, returned a certain number of articles/literature resources. Some keywords (including child and parent nodes) coincidentally shared the same articles/reference materials. This is clearly a case of probability with replacement, in which a number of items could be selected from the same source and returned. At a later time, a different item (or the same item) is selected from the same source and also returned. The percentage probability that the quantity of files identified contains these components/keywords is mathematically represented as:

$$P_{\%}(component) = \frac{N_{component\ files}}{N_{total\ files}} \times 100\% \qquad (2.1)$$

where $P_{\%}(component)$ is the percentage probability of the quantity of files collated containing a component, $N_{component}$ is the number of files that contains the component, $component$, and N_{total} is the total number of files. To illustrate the computation of the percentage probability of the *Human* component, I applied Equation (2.1). That is, if the number of files containing the *Human* component (N_H) is 88, and $N_{total\ files}$ is 115, then the percentage probability of the *Human* component is calculated as:

$$P_{\%}(H) = \frac{N_H}{N_{total\ files}} \times 100\% = \frac{88}{115} \times 100\% = 76.52\%$$

Equation 2.1 was also applied to other components (both parent and child components). Chapter 3 discusses the major components that were identified from the systematic review.

Chapter 3 : Results

3.1 Introduction

This section discusses the Word Cloud Diagram that was obtained from the NVivo document analysis software. Figure 3.1 shows frequently occurring words that overlap with the scoping architecture and the overall objective of the research, which further provides an overview of studies carried out by the featured authors. From the word summary, possible themes were identified, which broadened the search purview and facilitated the seamless grouping of the acquired keywords. These words were classified into three categories/components/nodes, namely *Humans*, *Aquatic Environment* and *Terrestrial Environment* based on the scoping architecture. To illustrate, keywords such as “land”, “soil”, and “agriculture”, were classified under the *Terrestrial Environment* component, and keywords such as “water”, “fishing”, and “mangrove”, were classified under the *Aquatic Environment* component. Keywords such as “Humans” and “Health” were classified under the *Human* component. I carried out a text search on each word that was categorised under the identified component. This was done on the NVivo software by separately executing a text search query on each of these words. During the text search, three questions came to the fore: *What components of the ecosystem within the Niger Delta of Nigeria are affected by crude oil?, What are the significant effects of oil spills on these components?* and *How are these components affected?*

The Text search queries aided the investigation of these words and helped explore the context, use and meaning of these words. It also gave room to explore one it features known as *Word Tree.* The branches of the word tree indicated the many contexts in which words appear, which was particularly beneficial in highlighting all the author's points or views that surrounded the term sought after. The results of this search were created as nodes, which were opened and explored for detailed investigation. For example, a text search for *Humans* helped to understand the word context better. Figures 3.2 and 3.3 respectively showed that *Health* is the most prominent theme that appeared after conducting a text search on the keyword "*Humans"*, so these terms were further investigated and coded.

Figure 3.1: Word cloud diagram

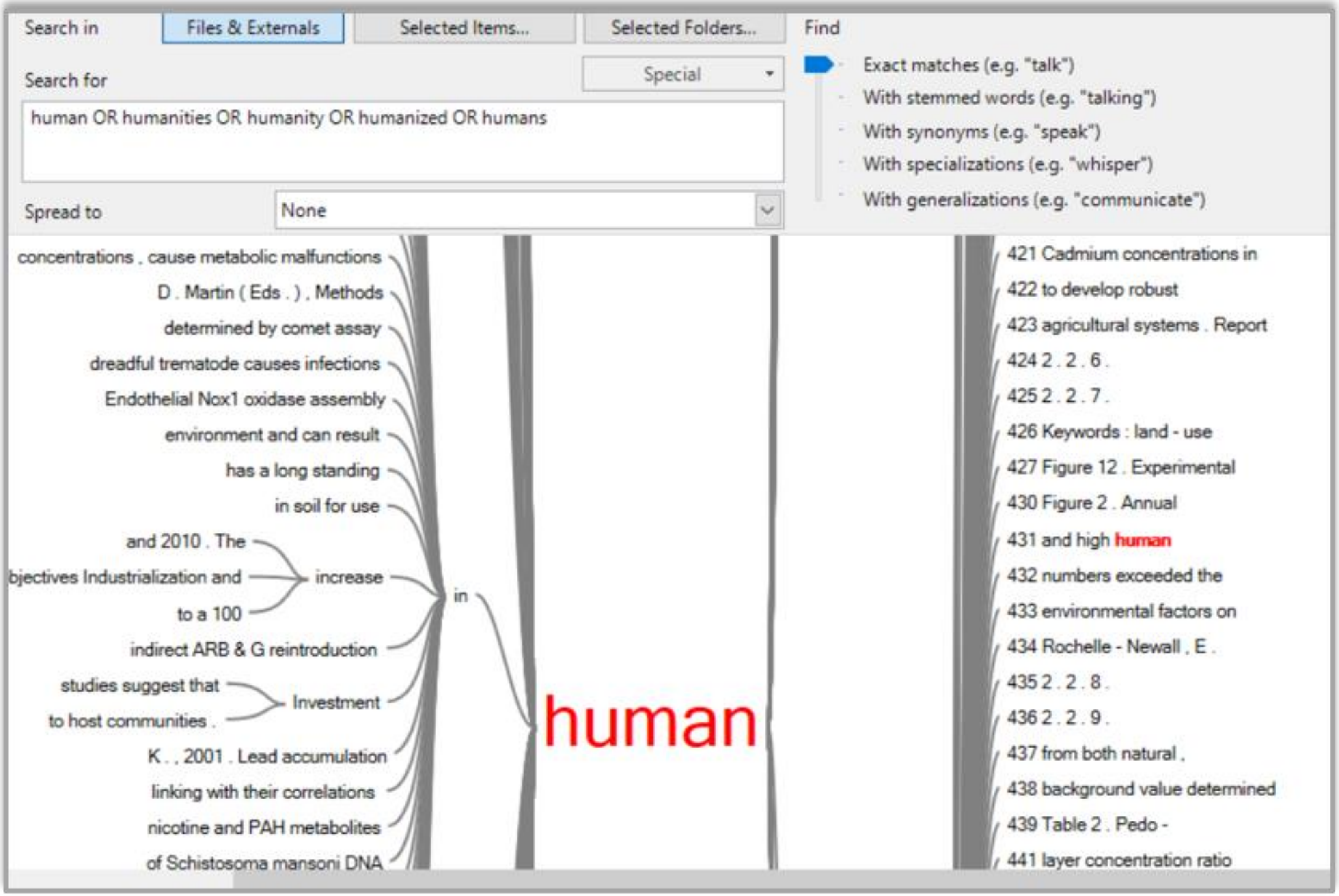

Figure 3.2: Word Tree text exploration of the Human component

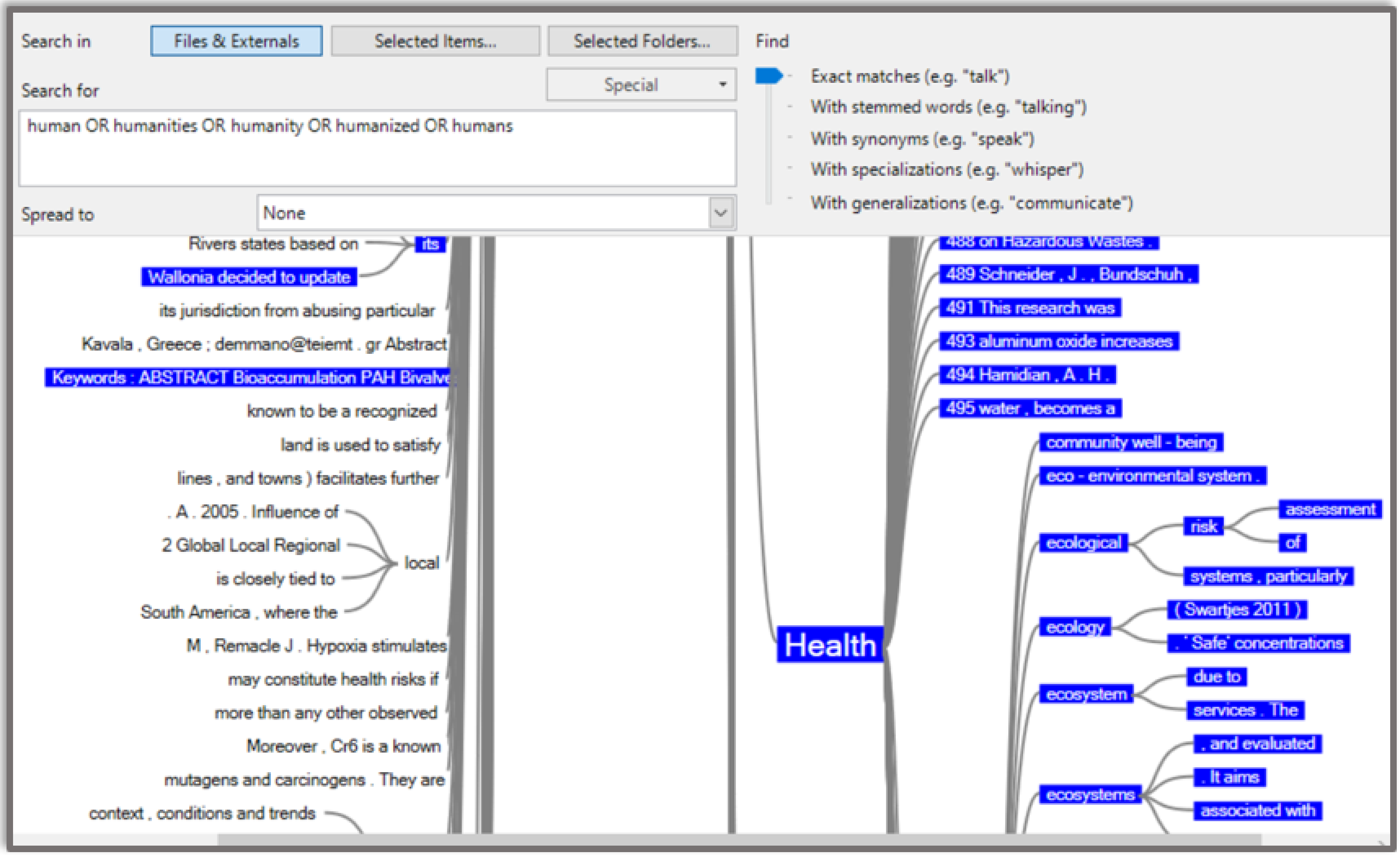

Figure 3.3: One of the Results of Word Tree text exploration of the Human component

The entire coding process contributed to the data analysis. For example, questions like "what is being said about humans?", "is it about one particular thing?" makes it easier to develop theories, see patterns and discrepancies. Summarily, the arrangement of these nodes was in hierarchies (parents and children). These hierarchies consolidate the questions and thoughts that arose while exploring text search, which were helpful in not just answering just answering the broader research question but also helping to address the research goal. These questions resulted in the creation of manageable node structure (Figure 3.4). The overall hierarchical relationship between the parent nodes and their children are shown in Figure 3.5. The hierarchy consists of the parent node, *Layer 1*, *Layer 2* and *Layer 3*. While *Layer* 3 has components that direct child nodes to *Layer 2*, *Layer 2* has components that are direct child nodes to *Layer 1*. The components of *Layer 1* are child nodes to *Parent Node*.

The systematic review yielded 115 full-text articles analyzed. Of the 115 articles considered, 76.5% [N(files) = 88] reflected studies on the impacts of crude oil on humans. However, the impact of this phenomenon on aquatic [N(Files) = 79] and terrestrial (N(Files) = 79] is each 68.7% of the articles analysed. The subsequent subsections discuss each component impacted by crude oil spills in the Niger Delta as it relates to the objectives of this study.

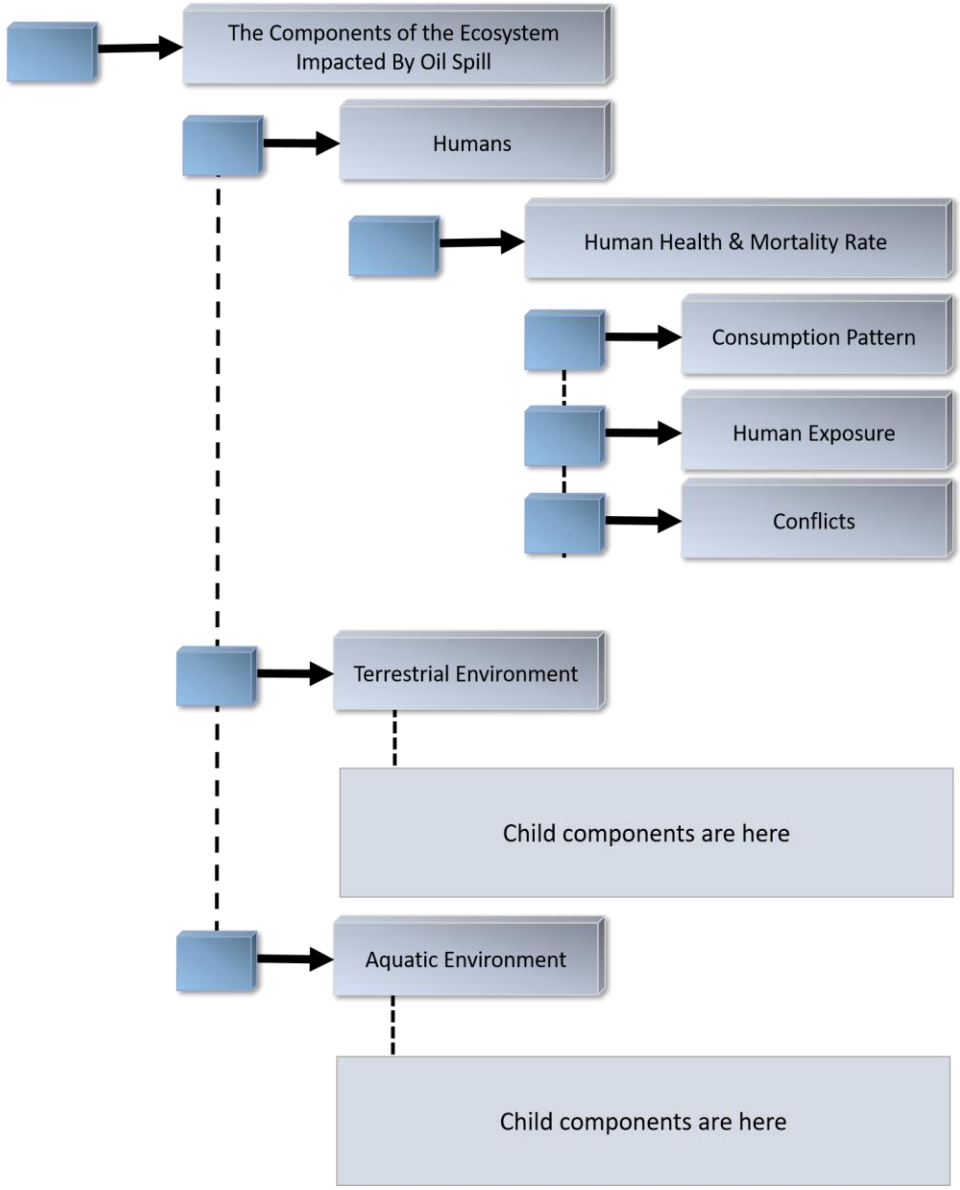

Figure 3.4: Excerpt of the relationship between the parent nodes and child nodes

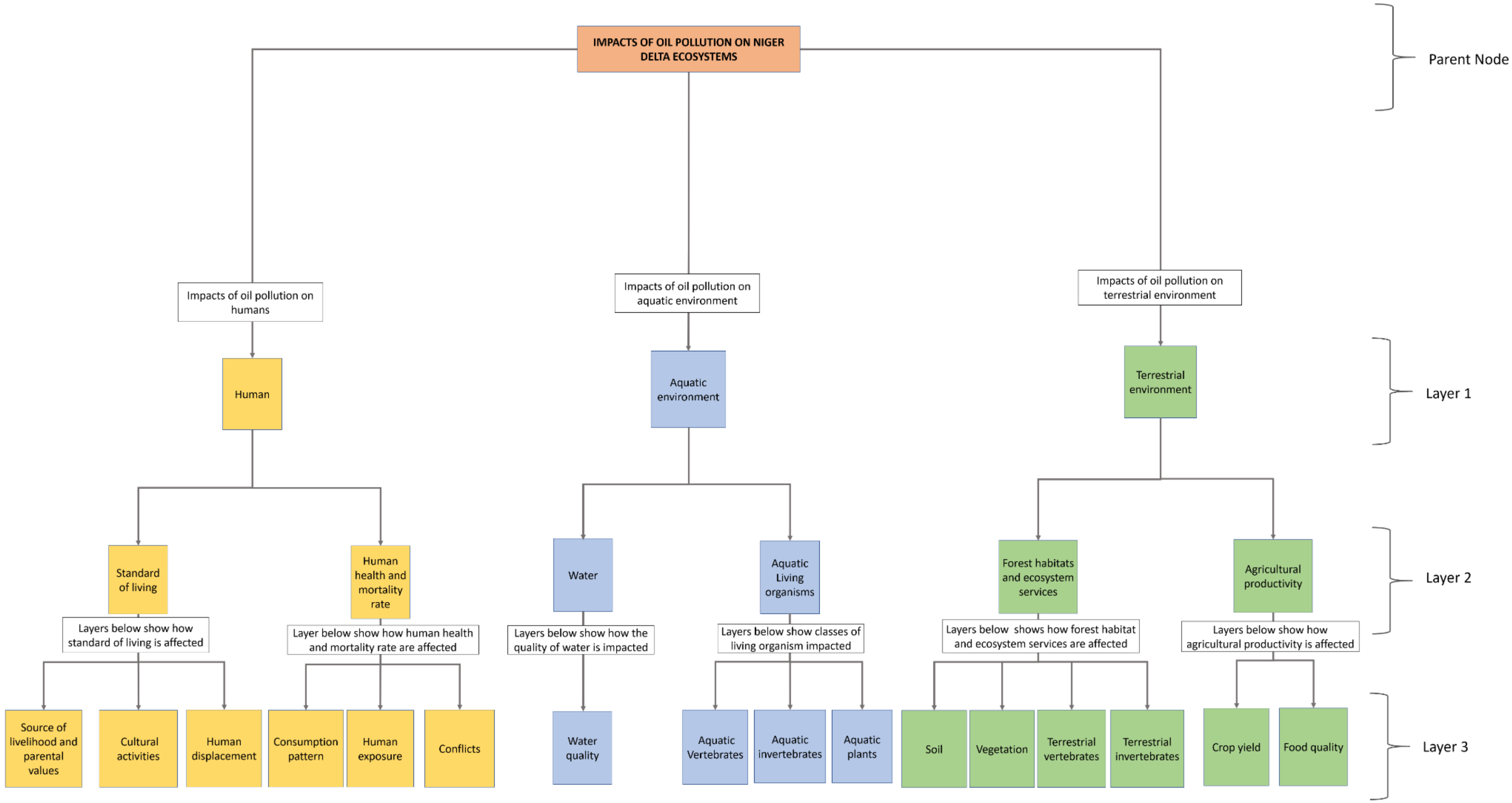

Figure 3.5: Result summary of the systematic literature review on impact of oil pollution on the Niger Delta Ecosystem

3.2 Human

Exploring the *Human* component (the parent node) impacted by crude oil pollution in the Niger Delta yielded two child nodes, namely, *Human Health and Mortality Rate* and *Standard of Living* (as illustrated in Figure 3.5). While *Standard of Living* accounts for 58.0% [N(Files)=51] probability, the *Human Health and Mortality Rate* accounts for 83.0% [N(Files)=73] of the queries obtained from the parent node (*Human* component). The summary of the percentage probability for the *Human* component and its child components are presented in Table 3.1.

Table 3.1: Percentage probabilities for the Human component and its child components (nodes) with respect to the immediate parent nodes

Component	Size of component	Total Number of files corresponding to the component	Percentage probability computation with respect to the immediate parent node
H	$N_H = 88$	$N_{total\ files}$ = 115	$\boldsymbol{P_{\%}(H) = \frac{N_H}{N_{total\ files}} \times 100\% = 76.5\%}$
HHMR	$N_{HHMR} = 73$	N_H	$P_{\%}(HHMR) = \frac{N_{HHMR}}{N_H} \times 100\% = 83.0\%$
CP	$N_{CP} = 41$	N_{HHMR}	$P_{\%}(CP) = \frac{N_{CP}}{N_{HHMR}} \times 100\% = 56.2\%$
HE	$N_{HE} = 22$	N_{HHMR}	$P_{\%}(HE) = \frac{N_{HE}}{N_{HHMR}} \times 100\% = 30.1\%$
CT	$N_C = 17$	N_{HHMR}	$P_{\%}(CT) = \frac{N_{CT}}{N_{HHMR}} \times 100\% = 23.3\%$
SL	$N_{SL} = 51$	N_H	$P_{\%}(SL) = \frac{N_{SL}}{N_H} \times 100\% = 58.0\%$
SLP	$N_{SP} = 37$	N_{SL}	$P_{\%}(SP) = \frac{N_{SlP}}{N_{SL}} \times 100\% = 72.5\%$
CA	$N_{CA} = 32$	N_{SL}	$P_{\%}(CA) = \frac{N_{CA}}{N_{SL}} \times 100\% = 62.7\%$
HD	$N_{HD} = 16$	N_{SL}	$P_{\%}(H) = \frac{N_{HD}}{N_{SL}} \times 100\% = 31.4\%$

Table 3.1 also shows a stepwise guide for calculating the percentage probabilities for the *Human* component and its child components. In the table, N_{HHMR}, N_{CP}, N_{HE}, N_{C}, N_{SL}, , N_{CA}, N_{SLP}, and N_{HD} respectively represents the number of articles retrieved that showed significant research in areas that pertains to *Human Health and Mortality Rate* (HHMR), *Consumption Pattern* (CP), *Human Exposure* (HE), *Conflicts* (CT), *Standard of Living* (SL), *Source of Livelihood and Parental Values* (SLP), *Cultural Activities* (CA), and *Human Displacement* (HD) components. It should be noted that N_{HHMR} is a child of N_{H}; N_{CP}, N_{HE}, and N_{CT} are all child nodes of N_{HHMR}; and N_{CA}, N_{SLP}, and N_{HD} are child nodes of N_{SL}. Table 3.2 also shows the percentage probabilities of the Humans component and its child components with respect to the total number of files acquired, N_{total}.

Table 3.2: Percentage probabilities for the Humans component and its child components (nodes) with respect to total number of files

Component	H	HHMR	CP	HE	CT	SL	SLP	CA	HD
Percentage Probability with respect to $N_{total\ files}$, i.e., $P_{\%}(c) = \frac{N_c}{N_{total\ files}} \times$ *100%*	*76.5%*	63.5%	35.7%	19.1%	14.8%	44.3%	32.2%	27.8%	13.9%

3.2.1 Human Health and Mortality Rate

The document analysis revealed that oil pollution threatens human health and increases the mortality rate through several means. The highlighted themes from this analysis are *consumption patterns, human exposure* and politically incited *conflicts* in the Niger Delta region. A total of 73 documents showed interest in the threat to human health and the mortality rate caused by oil pollution. *Consumption Pattern* accounts for 41 full-text articles (covering 51% of *Human Health and Mortality Rate*), which shows that consumption patterns are most studied as it relates to increased mortality and unwholesome health conditions. Respectively, human exposure and conflicts account for 22 documents (making up 28%) and 17 documents (making up 21%) of the articles reported in the *Human Health and Mortality Rate* category.

3.2.1.1 Consumption Pattern

In light of this study, consumption patterns are pathways through which humans achieve their dietary needs, primarily from both aquatic and terrestrial resources within their reach. In the Niger Delta region, cases of oil spillage, especially those in the hinterland, were not reported promptly (Amnesty International, 2018; Mahmoud, 2017). When reported, these incidents of oil spillage are often referred to as “minor” incidents. Even though some post-spill remediation exercises were underway, it did not include the affected remote areas (Agbonifo, 2016). Hence, these areas easily facilitate the retention of excess crude oil pollutants in the environment. The possibility of humans coming in contact with toxic and carcinogenic pollutants, such as polycyclic aromatic hydrocarbons (PAH) and other organic and inorganic chemical compounds present in crude oil is on the high side. PAH is a group of massive aliphatic and aromatic hydrocarbons in order of 10,000, containing two or more combined aromatic rings--and other hydrocarbons (Onwurah et al., 2007; Shen et al., 2014; Nwineewii and Marcus, 2015). PAH has been classified by the United States Environmental Protection Agency (USEPA) as a priority component responsible for persistent environmental pollution because it is the most toxic pollutant in crude oil (Adeyeye, 2020). From the analysis of the *Consumption Pattern* component, PAH makes up about 70% of the major chemical components found in crude oil. Heavy metals (Etuk et al., 2020), which make up the remaining 30% of toxic crude oil chemical composition, also cause health problems to the local population in the Niger Delta. These heavy metals include Cadmium (Cd), Lead (Pb), and Mercury (Hg). There are several pathways through which petroleum pollutants are ingested into the body systems of rural dwellers in the Niger Delta region (Okonokhua et al., 2007). Figure 3.5

gives a cursory view of possible pathways that people in Niger Delta, Nigeria, consume contaminated food.

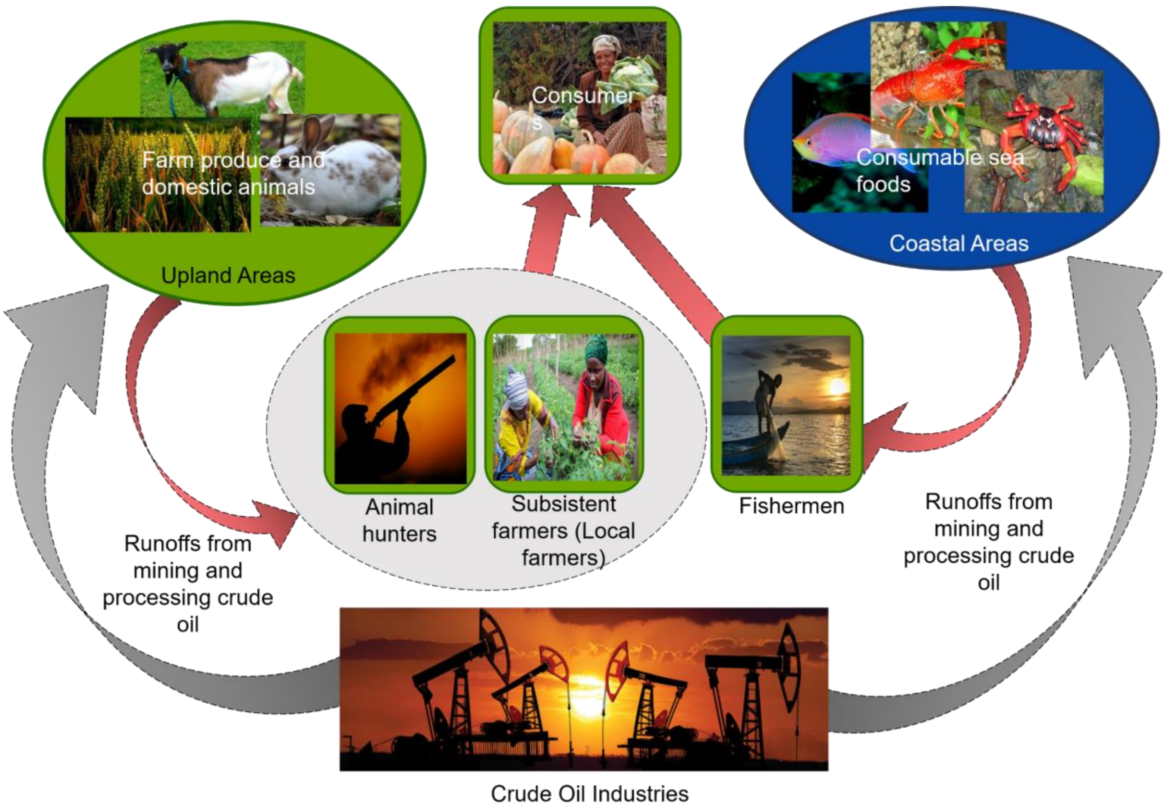

Figure 3.6: Pathways through which humans ingest crude oil pollutants

From Figure 3.4, during the transmission and intermittent storage of mined crude oil and petroleum byproducts, and sometimes usage of oil dispersant for cleaning oil spills, there are usually runoffs from vehicles and conveying systems, such as trucks, tankers, and pipelines (Anyanwu & Ejem, 2020; Enegide & Chukuma, 2018). These runoffs enter water bodies that serve as commercial fishing hubs in the coastal areas and agricultural lands for farming. Besides, most subsistence farmers depend on farm produce obtained from these agricultural lands for their livelihood. Local fishers make a living by selling fishes, crabs, and other edible marine vertebrates and invertebrates to the local and foreign expatriates working in the oil and corporate institutes. Most farmers, hunters, and fishers may be unaware or unconcerned about the level of crude oil pollutants already present in their foods. Even if they do, most may not care because they have no other way to make ends meet. In the end, a large percentage of the population feeds on these adulterated foods (Okoye et al., 2021). They unknowingly absorb a large amount of poisonous crude oil pollutants into their body system (Lawal, 2017). In addition, most rural dwellers in these coastal areas rely heavily on groundwater and river water for drinking (Onwurah et al., 2007; Daka and Ugbomeh, 2013; Ayanlade & Howard, 2016). There are other pathways through which these substances get ingested into their body system and cause profound health implications. However, the coverage obtained by querying *Consumption Pattern* provided information about several health consequences linked to the introduction of poisonous petroleum toxicants in the body systems of Niger Delta locals (either by directly consuming contaminated food or ingestion by drinking contaminated water) (Abonyi, 2020; Nriagu et al., 2016). The introduction of crude oil toxicants into the body system occurs by consuming contaminated drinking water, consuming adulterated foods, and exposure to noxious gases in the environment (Onyemachi, 2012; Ramirez et al., 2017). The aftermath of this usually results in a wide range of diseases and infections. Below are some common diseases associated with oil spillage.

(a) *Pulmonary Diseases:* When poisonous gases are released into the atmosphere by surrounding oil industries in the Niger Delta (primarily through gas flaring), people unconsciously inhale these gases (Obida et al., 2017). These gases impair their respiratory functions; in addition (Obida et al., 2017). The Niger Delta population living around polluted sites are the worst hit. Arguably, it has been established that the Niger Delta region has the highest number of pulmonary-related health challenges compared to other regions in Nigeria, having reached a record level (Nriagu, 2011; Ana, 2011). This is not a surprise because of the environmental hazards and pollutants introduced by oil industries in the region.

(b) *Cancer*: This occurs in the form of neoplasm or tumour, caused by carcinoma, a fallout of smoke and other harmful industrial pollutants (Moslen et al., 2019). Most of these pollutants are from oil industries, which affect the host communities and industrial workers in the Niger Delta region. Gases inhaled led to different variants of cancer, such as cancer of the lungs and cancer of the kidney (Ramirez et al., 2017). In addition, a large proportion of crude oil constituents are lipophilic (Onwurah et al., 2007) and thus, exert toxicity in a cellular environment by competing with some endogenic pathways. This condition causes enzyme deactivation and forms complex products that damage lipid membranes. It also changes the protein structure of deoxyribonucleic acid (DNA) and other macromolecules within the cell (Orisakwe et al., 2004; Braide et al., 2011).

(c) *Congenital and metabolic diseases:* Constant exposure of pregnant workers to these pollutants can give birth to abnormal children (Oghenetega et al., 2020a). Their unborn child's growth and development can be grossly affected (Hodal, 2017). The retrospective study by Oghenetega et al. (2020a) provided evidence to support this claim and confirmed that high levels of exposure to crude oil pollutants are more likely to be responsible for stillbirth and infant death cases. By intentionally improving spurious association within the data gathered, the authors reconfirmed that overexposure of women to crude oil pollutants only increases the infant death rate (Oghenetega et al., 2020b).

(d) *Contagious Diseases:* Disease vectors such as bacteria, viruses, rickettsia, and parasitic organisms (e.g., plasmodium from anopheles' mosquitoes) or zoonotic organisms infected by insects found in the forests where exploratory activities occur can potentially transmit contagious diseases such as; malaria, bubonic plague, schistosomiasis, leishmaniasis, and coronavirus (Winemiller, 2018, Dimkpa et al., 2019). Some animals in the forests might have contracted these diseases when captured while carrying out exploratory activities. The consumption of these animals can lead to salmonella and tapeworm infections (Adekola et al., 2017).

(e) *Psychological Disorder:* Continuous exposure to oil pollution can also lead to severe psychological distress, including depression, neurological impairment, post-traumatic stress disorder, and many more (Environmental Pollution Center, 2021). Akpofure et al. (2000) carried out a study on the post-impact assessment of the acute damaging effects of oil spills in the Niger Delta between 1998 and 2000 showing that there was an increase in anxiety disorders and phobic disorders for those exposed to crude oil pollution. Some subjects were also found to be schizophrenic, perplexingly neurotic, and having agoraphobic tendencies and disorders (Akpofure et al., 2000).

3.2.1.2 Human Exposure

The *Human Exposure* component gives information about how the Niger Delta population is directly exposed to toxic pollutants in petroleum products rather than through food and water consumption. I conjecture that some educated Niger Deltans, who understand their environment's prevailing condition, employ safety measures, such as personal hygiene, boiling water, and administering preventive medication. Arguably, a more significant percentage of the region's population, most of which has little or no education, could be at greater risk. Nonetheless, both the educated and uneducated population would have to cope with the continuous exposure to petroleum hydrocarbons since they live perpetually in this region.

Oil workers and drilling engineers are at risk of exposure to excess crude oil pollutants (Orisakwe, 2021). These people often live in proximity to the drilling sites and oil fields, inhaling volatile chemical components and aromatic hydrocarbons while performing their legitimate duties (Ordinioha & Brisibe, 2013; Etuk et al., 2020; Onyena & Sam, 2020; Ramirez et al., 2017). Additionally, while cleaning up dispersed oil in the environment, the contractors responsible for this occasionally come from the urban areas to the Niger Delta. Other health implications highlighted in the review included "endocrine system disruption", "nervous system inhibition and disruption", respiratory disorders, "developmental and carcinogenic effects", "headaches", "skin symptoms", and "back pain" (Nriagu et al., 2016; Onyena & Sam, 2020; Orisakwe, 2021). Long-term physiological implications are also of concern and include shortened life expectancy, deformation in children, reduction in the productive capacity of the populace, leukemia, emotional trauma, intensified asthma, and asthma bronchitis (Omeire et al., 2014).

However, the rural population in oil-producing communities of the Niger Delta are even at greater risk, given their lack of awareness of the dangers of crude oil pollution. Regrettably, they experience extreme heat emitted from gas flares, and noisy drilling machines, causing general discomfort (Omeire et al., 2014; Orisakwe, 2021). More so, their homes show traces of the level of damage caused by incomplete combustion of flared gas. Soot from these flares are deposited chiefly on buildings and properties close to oil production sites. The physical living environment has now become inhabitable, causing them to have psychological and economic stress (Onyechi et al., 2016).

A holistic examination of the *Human Exposure* component has shown that the common health conditions of people living in the oil-producing area of Niger Delta are respiratory diseases and cancer growth. The inhalation of byproducts from incomplete hydrocarbon combustion is the primary path to noncontact exposure to hydrocarbons in the region.

3.2.1.3 Conflicts

The coding stripes for *Humans* also produced reported cases of conflict and restiveness in some communities of the Niger Delta region (Uyigue & Agho, 2007; Eboh, 2019). The articles considered in the review broadly linked hostilities in the region to environmental devastation by multinational oil companies and neglect by the Federal Government of Nigeria (Ijekeye, 2019).

The indigenous Niger Delta people of Nigeria are versatile in agricultural practices, mainly farming and fishing. These activities have been a historical source of income for their families, which suggests that farmers and fishers cannot survive without fertile agricultural lands and unpolluted water bodies. Unfortunately, this narrative has, over the years, changed due to oil pollution and negligence, which has made teeming Niger Delta youths to resort to forming several agitation groups and militant groups to express their grievances towards the Federal Government (Albert et al., 2017; Eluozo, 2018). This agitation is because they have lost their lands and waters to crude oil extraction activities (Onyemachi, 2012). Thus, they have no other means of survival. This situation became even more volatile due to the outright negligence by the multinationals and the Federal Government of Nigeria (Ofulu, 2017). Some notable examples of violence and conflict in the region are "expulsion of Shell Petroleum Company from Ogoni land in the Niger Delta in 1990s due to over 20 years of exploration without a corresponding infrastructural development" and clashes between military personnel attached to the management staff of Total and local youths of Odiemerenyi community in Ahoada East of River State (Numbere, 2021; Uyigue & Agho, 2007; FAO, 2018).

Furthermore, about 70% of article references indicated that the environmental damage due to crude extraction in the Niger Delta region had given birth to other social vices and social issues (Eluozo, 2018; Numbere, 2021). Examples are inter-and intra-communal clashes (Uyigue & Agho, 2007). Federal Government officials, multinational oil companies, and compromised elders of the Niger Delta communities reportedly instigated these activities (Albert et al., 2017). This divide-and-conquer strategy protects the interest of the oil companies and the Federal government at the expense of the people (Albert et al., 2017). In addition, there has also been frequent pipeline vandalization and bombing by aggrieved Niger Delta militant and agitation groups (especially those of Ijaw and Ogoni) (Onyemachi, 2012). This act of vandalizing installed oil pipelines has caused fire outbreaks, leading to loss of lives and properties (Uyigue & Agho, 2007). Examples of fire accidents resulting from vandalization occurred in 1998 in Jesse Village, Ekakpamre, Ughelli, Delta State, Nigeria, where 1000 lives were lost (Uyigue & Agho, 2007). Another incident occurred in Nngiji and Umuegbede, Abia State, Nigeria, in 2000, where 50 people lost their lives to an inferno caused by pipeline vandalism. Fallouts from this unprecedented situation have increased kidnapping, robbery, poverty, crisis and unrest in the region.

3.2.2 Standard of Living

Standard of living is a measure of the level of wealth and comfort of a community, state, country or region. In this study, 51 files were classified under the component, *Standard of Living*. Querying this component yielded other children nodes, including *Source of Livelihood and Parental Values*, *Cultural Activities*, and *Human Displacement.* From this result, there is 72.5% [N(Files) = 37] probability that the articles discussed mostly about the *Source of Livelihoods and Parental Values*, 62.7% [N(Files) = 32] emphasised on the *Cultural Activities* and the remaining 31.4% [N(Files) = 16] examined the *Human Displacement* component. The remainder of this subsection investigates each of these components in relation to how they affect humans, particularly those living in the Niger Delta communities.

3.2.2.1 Source of Livelihood and Parental Values

The Niger Delta livelihood activities determine the state of their local economies and social life because they influence the forces of demand and supply, as well as the purchasing power of the inhabitants. Following more than four decades of crude oil extraction in the region, fertile agricultural lands have now become desolate due to the cumulative effect of crude oil pollution in the Niger Delta environment (Oteh & Eze, 2012). Hence, nitrogen fixing microorganisms that improve soil fertility are killed by the toxins present in crude oil, which reduce crop yields by a significant amount. Surprisingly, it was also uncovered that seismic activities caused by oil exploration also contributed to the depletion of fertile farmlands (Onyena & Sam, 2020; Oriaku et al., 2017). Also, continuous gas flaring contributes to acid rain that also lowers soil fertility (Uyigue & Agho 2007; Orisakwe, 2021). This had a sweeping effect on rural livelihood (Omeire et al., 2014; Agbagwa & Ndukwu, 2014). Similarly, fishing waterways have been inundated with high volumes of spilled crude oil, killing fishes, crabs, periwinkle and other seafood (Eluozo, 2018).

These experiences negatively impact the overall livelihoods of the rural dwellers and eventually they are impoverished (Amnesty International, 2019). As a result, the incidence of poverty, occupational dislocation and unemployment in the regions has over the years increased at an alarming rate, despite the fact that their communities are hosts to multinational oil companies (Onyena & Sam, 2020; Albert et al., 2017). Even so, the companies did not employ most of these locals who had no other source of livelihood, probably because they had no employable skill set (Uyigue & Agho, 2007). Based on the coding stripes obtained, the oil spill that took place at Oruma, Bayelsa State in 2005, exemplifies the impact of oil pollution on livelihoods. In the Oruma communities, oil spills from high-pressure Shell pipelines rapidly spread to many fish ponds in nearby communities, which relied on them for livelihood and food, killing large numbers of fishes (Onyemachi, 2012). Oil pollution in the region has also affected the local tourism industry, which contributes to the local economy (Zhang et al., 2019; Numbere, 2021). Tourists are forcefully driven out of the community because of the inhabitable state of the environment, thus, leading to further economic decline.

Decline in parental values is one of the prominent consequences of oil pollution in the region (Albert et al., 2017). Parents and guardians whose sole source of income is fishing and farming are unable to afford sending their wards to school in the event of oil pollution (Albert et al., 2017). These children are out of school for a protracted period of time. In the midst of environmental pollution, restiveness amongst youths increases the insecurity situation of the region. Hence, the traditional learning lifestyle common amongst the children is lost (Albert et al., 2017). Their predicament is compounded by the high cost of living and transportation.

3.2.2.2 Cultural Activities

Social structure, artefacts, historical monuments and cultural heritage define who a people are. The indigenous people of Niger Delta communities and historic cultural heritage are inseparable (Chukwuka et al., 2018). However, the advent of crude oil exploration and continued gas flaring and oil pollution in the region has led to loss of the region's socio-cultural heritage (Mogaji, 2018). Many historical monuments and artefacts have been lost to acid rain (Orisakwe, 2021). Seasonal cultural activities have not been spared either (Onyena & Sam, 2020). For instance, the culture of bathing with community members in a river to usher in a new year of blessings has been supposedly abolished because the rivers which may have been used for these practices were polluted and thus are unideal for this purpose (Onyena & Sam, 2020). Thus, the native people have lost most of their collective identity as a result of the conversion of agricultural lands and industrial lands (Chukwuka et al., 2018).

Additionally, traditional practices such as worship of gods and goddesses have been stymied by the building of oil installations and flow stations in forests and strategic areas (Chukwuka et al., 2018).

As a result, communities have lost their belief system and social values. Recreational activities and beach aesthetics have equally been affected by oil pollution (Mogaji et al., 2018; Arimoro et al., 2011). Children and fun-seeking adults can no longer swim in the beaches because the shores have been heavily polluted by crude oil and dead seafood. Because of the loss of mangrove forests, activities such as mat weaving, local gin production, boat building and palm wine tapping have diminished and are almost non-existent (Eleke et al., 2019).

3.2.2.3 Human Displacement

The inability of the Nigerian Government to regulate the extraction of crude oil and create alternative sources of income for Niger Delta communities impacted by pollution has resulted in internal displacement and occupational displacement (Eboh, 2019). Over the years, the rate of rural-urban migrations has increased with crude oil pollution (Uyigue & Agho, 2007). Paradoxically, the towns and cities receiving these migrants have insufficient resources to create employment opportunities (Onyena & Sam, 2020). The population explosion is already pressuring the limited resources (Onyena & Sam, 2020). Unfortunately, the population explosion has an undesirable effect on the employment figures of such cities. However, the elderlies that still depend on agriculture for sustenance, accepted their fate and remained in the villages, dealing with the hardship associated with oil pollution (Langangen et al., 2017; Uyigue and Agho, 2007). In addition, the unavailability of arable farmlands has forced many youths out of Ogoni land (one of the communities in Niger Delta) to Port-Harcourt, Omoku and Eleme (Onyena & Sam, 2020). Furthermore, the oil spill of Osima in 1998, which caused a fire outbreak that lasted for eight days, forced 130,000 members of the communities from their homes (Onyemachi, 2012). This incident forced them to migrate to neighbouring communities because the inferno had ravaged their communities.

3.3 Aquatic Environment

During the analysis of the Aquatic *Environment* component, 79 articles relating to this theme were collected. Analysing the effects of crude oil pollution on the *Aquatic Environment* theme yielded two children components, namely *Aquatic Living Organisms* and *Water* (described in Figure 3.5). These components are vastly impacted by oil pollution. The coding stripes obtained from this exploration evidenced that 78.5% [N(Files)=62] of the articles collected showed the impact of oil pollution on *Aquatic Living Organisms* and 42% [N(Files)=45] showed its impact on *Water Quality*. The percentage probabilities for the child components of Water Quality and Aquatic Living Organisms are shown in Table 3.3.

Table 3.3: Percentage probabilities for the Aquatic Environment component and its child components (nodes)

Component	Size of component	Total Number of files corresponding to the component	Percentage probability computation with respect to the immediate parent node
AQE	$N_{AQE} = 79$	$N_{total\ files} = 115$	$P_{\%}(AQ) = \frac{N_{AQE}}{N_{total\ files}} \times 100\% = 68.7\%$
AQL	$N_{AQL} = 62$	N_{AQE}	$P_{\%}(AQL) = \frac{N_{AQL}}{N_{AQE}} \times 100\% = 78.5\%$
AQV	$N_{AQV} = 47$	N_{AQL}	$P_{\%}(AQV) = \frac{N_{AQV}}{N_{AQE}} \times 100\% = 59.5\%$
AQI	$N_{AQI} = 24$	N_{AQL}	$P_{\%}(AQI) = \frac{N_{AQI}}{N_{AQE}} \times 100\% = 30.4\%$
AQP	$N_{AQP} = 35$	N_{AQL}	$P_{\%}(AQP) = \frac{N_{AQP}}{N_{AQE}} \times 100\% = 44.3\%$
W	$N_W = 45$	N_{AQE}	$P_{\%}(W) = \frac{N_W}{N_{total}} \times 100\% = 39.1\%$
WQ	$N_{WQ} = 34$	N_W	$P_{\%}(WQ) = \frac{N_{WQ}}{N_W} \times 100\% = 75.6\%$

Table 3.3 also shows the procedure for computing the percentage probability for the *Aquatic Environment* component and its corresponding child nodes. From the table, AQE, AQL, AQV,

AQI, AQP, W, and WQ, respectively represents the *Aquatic Environment* component, *Aquatic Living Organisms*, *Aquatic Vertebrate*, *Aquatic Invertebrate*, *Aquatic Plant*, *Water*, and *Water Quality* components. While AQL and W are child nodes of AQE; AQV, AQI, and AQP are child nodes of AQL; and WQ is a child component of W. Table 3.4 also shows the percentage probabilities of the Humans component and its child components with respect to the total number of files acquired, $N_{total\ files}$.

Table 3.4: Percentage probabilities for the Aquatic Environment component and its child components (nodes) with respect to the total number of files

Component	AQE	AQL	AQV	AQI	AQP	W	WQ
Percentage Probability with respect to N_{total}, i.e., $P_{\%}(c) = \frac{N_c}{N_{total\ files}} \times 100\%$	68.7%	53.9%	40.9%	20.9%	30.4%	39.1%	29.6%

Subsequent subsections will discuss extensively about the impact of crude oil pollution on the Niger Delta aquatic environment, aquatic living organisms and water resources.

3.3.1 Aquatic Living organisms

The introduction of crude oil into the Niger Delta aquatic ecosystems from accidental oil spills and other anthropogenic activities impacts aquatic life. This is due to the presence of petrogenic PAHs in petroleum which have mutagenic, toxic, and carcinogenic implications. In recent times, the continued introduction of PAHs from crude oil in aquatic habitats has caused a deterioration of aquatic biota (Baali et al., 2016). Evidence from the literature has shown that there are traces of petrogenic as well as pyrogenic PAH in the sediments of rivers and streams surrounding the Niger

Delta aquatic ecosystem. Sojinu et al. (2010) studied the concentration levels of sediments in certain regions of the Niger Delta. The study revealed that the highest concentration of PAH (about 331 ng/g)—that essentially contained 2-ring structures such as naphthalene—was found in Oginni, which is an area dominated by oil wells and oil processing facilities in Niger Delta, Nigeria. This level of concentration was linked to the intense oil exploratory activities in the area, which led to pipeline leakages and the concomitant seepage into water bodies. A similar investigation was carried out by Ihunowo et al. (2019) who sought to measure the distribution of PAHs along Woji creeks in the Niger Delta. Out of 16 different classes of PAH investigated, only 11 were detected in the water and sediment samples obtained from the creeks, even though some classes such as Naphthalene, Phenanthrene, Pyrene and Indenol (1,2,3,-cd) pyrene and Benzo[(g),(h),(i)] perylene were not detectable (Ihunowo et al., 2019). In common with Sojinu et al. (2010), the dominant PAH in the Woji creeks were mostly 2- and 3-ring low molecular weight PAHs, which were dominant over 4-, 5-, and 6- ring high molecular weight (HMW) PAHs. It was later speculated by Ihunowo et al. (2019) that the major cause of PAH contamination in the Woji creeks is the seepage of petroleum into the creeks. Out of the 62 files (containing 210 references) acquired for *Aquatic Living Organisms* component, 44% (N = 47) of the majority of the articles emphasised on *Aquatic vertebrates*, 33% (N = 35) discussed about *Aquatic Plants* and the remaining 23% (N = 24) covered *Aquatic Invertebrates*. The rest of this subsection describes the bioaccumulation and bioconcentration of PAH classes and their effects on aquatic vertebrates, invertebrates, and plants. A review of these effects is first undertaken, and thereafter exemplified by instances from some Niger Delta communities.

3.3.1.1 Aquatic Vertebrates

In a bid to measure the concentration of PAH in River Aqurinrin in the Degele Community of Sapele, Niger Delta, Olaji et al. (2014) collected samples of four different species of fish namely, Tilapia (*Oreochromis niloticus*), Catfish (*Clarias gariepinus* and *Heterobranchus longifilis*), and Liza falcipinnis. Naphthalene, an Low Molecular Weight (LMW) PAH was detected in all fish species collected, but *Oreochromis niloticus* had the highest concentration of LMW PAH (concentration range between 0.02 mg/kg; body weight/day and 0.94 mg/kg body weight/day) (Olaji et al., 2014). On the contrary, HMW PAH was not found inside any of the fish species (Olaji et al., 2014). Hence, River Aqurinrin in the Degele Community of Sapele, Niger Delta is sparingly contaminated by crude oil spills. This shows variations in the level of oil spills and contamination in the aquatic habitats within the Niger Delta communities.

In another study, the impact of 3-ring PAH, phenanthrene, on crustaceans (e.g., signal crayfish, *Pacifastacus leniusculus*) was studied to ascertain its effects on cardiac performance, oxidative stress response and tissue burden (Ainerua et al., 2020). Results from the research showed that phenanthrene tends to reduce the maximum possible heart rate of the signal crayfish, which could reduce the aerobic exercise capacity after a 15-day exposure of the fish to phenanthrene (Christou & Seals, 2008). However, this did not reduce the normal heart rate of the crustacean (Ložek et al., 2020). It was also observed that the exposure of the crustacean to PAH was responsible for the reduction in the likelihood of the signal crayfish surviving in its ecosystem.

The concentrated PAH easily gets into the tissues of marine mammals because they are absorbed through their gastrointestinal tracts which then spread to other tissues and sometimes settle in fatty tissues. The increasing concentration of PAH in the tissue can lead to physiological effects such as cognitive difficulties and impaired development (Webb et al., 2017). Aquatic organisms (such as fish) lose their ability to learn and explore after the exposure to dangerous levels of HMW PAH, which affect their ability to swim due to increased lethargy, anxiety, and reduction of social interaction, especially when exposed to phenanthrene (Brette et al., 2017). Furthermore, PAH induces developmental issues amongst organisms because of their skeletal framework malformation, leading to craniofacial deformation, jaw malformation and skeletal mineralization in some organisms (Rafikova et al., 2019). This, overall, leads to reduction in the weight and size of the aquatic organism. In fact, a study has revealed a strong correlation between reduction in size and level of contamination (Langangen et al., 2017).

3.3.1.2 Aquatic Invertebrates

The accumulation of HMW PAHs in aquatic habitats also causes bioaccumulation and bioconcentration in invertebrates (Stephansen et al., 2020). Through ultraviolet (UV) radiation photo-enhanced toxicity of PAHs, intermediate stages of aquatic microorganisms such as larvae and embryos will be subjected to a greater risk of toxicity due to their translucent and lightweight nature, facilitating their exposure to PAHs (Mace, 2017). To corroborate this claim, pioneering research was conducted to investigate the impact of PAHs as well as monohydrated PAHs (OHPAHs) on the embryogenesis of sea urchins obtained from the Tayama Bay Side of the Noto Peninsula (Suzuki et al., 2015). The spicule length and the messenger RNA (mRNA) of the *Hemicentrotus pulcherrimus* of spicule matrix protein 50 gene was measured after exposing the experimental samples to different concentrations of 4-hydroxybenzyl[a]anthracene (4-OHBaA) and benz[a] anthracene (BaA). The spicule length of the sea urchins was suppressed by 4-OHBaA with a concentration of either 10^{-8}M or 10^{-7}M. BaA, with concentration of 10^{-7}M significantly inhibited the length of the spicule (Hayakawa, 2018). However, no effect was recorded when the sea urchins were exposed to BaA with a concentration of 10^{-8}M (Hayakawa, 2018). It was further observed that the complexity of the sea urchins' mRNA decreased considerably when exposed to 4-OHBaA. This eventually causes malformation of the spicule in sea urchins.

Daka & Ugbomeh (2013) measured the level of bioaccumulation of PAHs in crab *Callinectes pallidus* that inhabits the upper Bonny Estuary area of Azuabie in the Niger Delta region of Nigeria. By collecting samples of sediments and crab samples from the estuary and quantifying the classes of PAH present, major carcinogenic PAHs, including Naphthalene, Benzo[a]pyrene, Benzo[a]Anthracene and Phenanthrene were detected (Daka & Ubgomeh, 2013). However, the concentration of these PAHs varied with seasons (rainy season and dry season). A similar study conducted by Moselm et al. (2019) sought to measure the concentration of PAH in bivalve (*Arca senilis* - blood cockles) and the associated health risks when the PAH-contaminated bivalve is consumed. During the analysis of bivalve samples, three indicators were assessed namely carcinogenic toxic equivalent (TEQs), Excess Cancer Risk (ECR) and Dietary Daily Intake (DDI). Values for each of these indicators were obtained based on the concentration of PAH in the experimental sample. The values of ECR and DDI obtained were below the threshold established by the United States Environmental Protection Agency (USEPA) (Moselm et al., 2019). Although these indicators suggest that the health risk involved in consuming PAH-contaminated *Arca Senilis* is minimal, regular monitoring of the PAH concentration in these invertebrates is recommended because of the capricious nature of these concentration levels.

3.3.1.3 Aquatic Plants

Hydrophyte/macrophytes are also affected by overexposure to PAH brought about by petrogenic pollutants, which could oftentimes lead to phytoaccumulation. Several studies have been carried out to detect the concentration levels of PAH in certain aquatic plants. These studies have buttressed the fact that aquatic floras are also affected by industry-induced pyrogenic pollutants. In a study by McConkey et al. (2009), the toxicity of a certain class of PAH called Phenanthrene (PHE) and photoproduct of PHE exposed the UV light, 9, 10 phenanthrenequinone (PHEQ) on marina bacteria, *photobacterium phosphoreum* and aquatic plant Lemna gibba (duckweed) was measured. The obtained results showed that the PHEQ variant of PAH significantly increased phytotoxicity. Comparatively, the toxicity of PHEQ when exposed to visible light increased more than PHE (McConkey et al, 2009). A related study highlighted the impact of these levels of toxicity on the plant species. These toxicity levels were indications of stunting of growth and degree of chlorosis as well as inhibition of photosynthesis in these aquatic plants (Huang et al., 1997; Huang et al., 1993). In order to comparatively determine the differences in the phytoaccumulation of aromatic and aliphatic pollutants in both submerged and emergent freshwater aquatic plants. Fan et al. (2018) measured the concentration of other organic pollutants, including polycyclic aromatic hydrocarbons (PAHs) and substitute PAHs (s-PAHs) such as oxy-PAHs, and sulphur-PAHs in both plant types (10 submerged and emergent plants from Lake Dianchi in Yunnan-Guizhou plateau close to Kunning, Yunnan, China. High levels of PAHs and s-PAHs were observed in the aquatic plants. However, the submerged aquatic plants had a higher concentration of pollutants than the emergent plants (Fan et al., 2018). Özen et al. (2017) undertook a study to assess the distribution of Macrophytes and the degree of PAH contaminants in some selected aquatic habitats in the industrial city of Kocaeli, Turkey. A perennial flowering plant called the European water-plantain (*Alisma plantago-aquatica*) obtained from four aquatic habitats located close to industrial facilities. By measuring the ratio of 8 PAH contaminants in A. *plantago*, it was established that aquatic plants nearest to industrial stations had the highest concentration of PAHs congeners (Özen et al., 2017). However, lower concentrations of the pollutants were observed in plants distant from industrial facilities (Özen et al., 2017). This literature survey is indicative of the presence of pyrogenic organic pollutants, majorly, PAH and its variants in aquatic plants, which could impact their overall growth and survival.

A similar study which involved the determination of the PAH levels of both wild and cultivated edible mushrooms was conducted by Igbiri et al. (2017). The authors collected samples of these mushrooms in triplicate from different locations of Port Harcourt, River State, Niger Delta, Nigeria. USEPA-16 PAHs concentration ranged from 0.02 mg/kg to 3.37 mg/kg. The significance of this research is that it would give insight about the dietary intake of both carcinogenic and non-carcinogenic USEPA-16 PAHs. *Pleurotus ostreatus*, a species of mushroom, tends to have higher bioaccumulation of BaP and BaBeq than other species considered, which indicates that its continuous consumption could lead to high life-time cancer risks (Igbiri et al., 2017).

3.3.2 Water

Water resources are one of the vehicles that transport crude oil pollutants from the oil field to aquatic vertebrates, invertebrates and plants. The presence of crude oil toxicants in water reduces the volume of dissolved oxygen, which leads to the suffocation of aquatic living organisms (Okpara & Kharlamova, 2018). These organisms eventually die, which leads to a reduction in the quality of water (Oteh & Eze, 2012). The following subsection will further examine the implication of crude oil pollution on water quality.

3.3.2.1 Water Quality

During data exploration, I acquired 45 articles (containing 146 references), of which 34 articles covered the *Water Quality* component. This number represents 75.6% of all the articles with contents related to the *Water* component. Water quality means the condition of water in terms of its chemical, physical and biological constituents, often with reference to its suitability for consumption. The chemical constituents that essentially affect the suitability of water for consumption, particularly for drinking are PAH, and heavy metals (Nwineewii and Marcus, 2015;

Enegide & Chukwuma, 2018). Usually, the concentration and toxicity of these chemical constituents are measured based on some metrics predefined by the World Health Organisation (WHO) and USEPA (Nwineewii & Marcus, 2015; Etuk et al., 2020). Some of the commonly known metrics are Target Hazard Quotient (THQ) and Hazard Index (HI) (Etuk et al., 2020). Water resources, such as groundwater, stream water and river water can lose their quality when exposed to oil pollution. These oil pollutions are caused by crude oil spills and are predominant during offshore drilling activities, leakages from oil installations and production water discharge (Abonyi, 2020; Onyena & Sam, 2020). Because the Bonny crude oil of Nigeria is light in nature and 45% of which accounts for PAH, the crude oil easily dissolves in water (Orisakwe et al., 2004). Typically, when this kind of crude find its way into water bodies, they affect the purity and quality of groundwater, ruining zooplanktons, phytoplankton and benthic organisms by reducing the concentration of dissolved oxygen, increasing the pH as well as the temperature of the water (Numbere, 2018). When it comes down to humans, the quality of drinking diminishes due to crude oil pollution. Hence, this leads to scarcity of potable drinking water, threatening public health and safety (Iwubeh et al., 2020).

Literature has evidence that confirms that a large proportion of the Niger Delta water resources have been contaminated. For instance, the University of Lagos' Faculty of Pharmacy investigated the major toxicological constituents of borehole water in the Niger Delta (mainly Delta state and Rivers state) (Onyemachi, 2012). It was discovered that well over 70% of the water samples collected from these regions contain Benzo pyrene, whose concentration is above the permissible standard as specified by the WHO. Similarly, the concentration of PAH in the Niger Delta creeks (Eleme and Okrika) was higher than the permissible level specified by USEPA (Nwineewii & Marcus, 2015). Another research sought to determine the concentration of heavy metals present in the Cross River Estuary. The study showed that Nikel (Ni), Cadmium (Cd) and Lead(Pb) were the three main heavy metals with HI and THQ indices relatively higher than those of Zinc (Zn), Copper (Cu) and Iron (Fe) (Etuk et al., 2020). On the whole, when the concentration and toxicological level of these water pollutants are higher than the allowable level, then the health risks are higher.

3.4 Terrestrial Environment

The *Terrestrial Environment* component (Figure 3.5) is made up of 79 articles. This component yielded two child components namely, *Forest Habitat and Ecosystem Services* and *Agricultural Productivity*. While *Forest Habitat and Ecosystem Services* constitute 69.6%[N(Files)=55] percentage probability, *Agricultural Productivity* constitutes 58% [N(Files)=75, N(Ref)=422] of the *Terrestrial Environment* component (Table 3.5). From the table, TE, FHES, SO, VEG, TV, TI, AP, CY, and FQ, respectively represents the *Terrestrial Environment* component, *Forest Habitats and Ecosystem Services*, *Soil*, *Vegetation*, *Terrestrial Vertebrates*, *Terrestrial Invertebrates*, *Agricultural Productivity*, *Crop Yield*, and *Food Quality* components. While FHES and AP are child nodes of TE; SO, VEG, TV, and TI are child nodes of FHES; and CY as well as FQ are child nodes of AP. Table 3.6 also shows the percentage probabilities of the Humans component and its child components with respect to the total number of files acquired, $N_{total\ files}$. Subsequent subsections elaborate these components.

Table 3.5: Percentage probabilities for the Terrestrial Environment component and its child components (nodes)

Component	Size of component	Total Number of files corresponding to the component	Percentage probability computation with respect to the immediate parent node
TE	$N_{TE} = 79$	$N_{total\ files}$ = 115	$P_{\%}(TE) = \frac{N_{TE}}{N_{total\ files}} \times 100\% = 68.7\%$
FHES	$N_{FHES} = 75$	N_{TE}	$P_{\%}(FHES) = \frac{N_{FHES}}{N_{TE}} \times 100\% = 95.0\%$
SO	$N_{SO} = 53$	N_{FHES}	$P_{\%}(SO) = \frac{N_{SO}}{N_{FHES}} \times 100\% = 96.4\%$
VEG	$N_{AVEG} = 45$	N_{FHES}	$P_{\%}(VEG) = \frac{N_{AVEG}}{N_{FHES}} \times 100\% = 81.8\%$
TV	$N_{TV} = 28$	N_{FHES}	$P_{\%}(TV) = \frac{N_{TV}}{N_{FHES}} \times 100\% = 51.0\%$
TI	$N_{TI} = 24$	N_{FHES}	$P_{\%}(TI) = \frac{N_{TI}}{N_{FHES}} \times 100\% = 43.6\%$
AP	$N_{AP} = 55$	N_{TE}	$P_{\%}(AP) = \frac{N_{AP}}{N_{TE}} \times 100\% = 69.6\%$
CY	$N_{CY} = 34$	N_{AP}	$P_{\%}(CY) = \frac{N_{CY}}{N_{AP}} \times 100\% = 45.3\%$
FQ	$N_{FQ} = 22$	N_{AP}	$P_{\%}(FQ) = \frac{N_{FQ}}{N_{AP}} \times 100\% = 29.3\%$

Table 3.6: Percentage probabilities for the Humans component and its child components (nodes) with relative to the total number of files

Component	TE	FHES	SO	VEG	TV	TI	AP	CY	FQ
Percentage Probability with respect to $N_{total\ files}$, i.e., $P_{\%}(c) = \frac{N_c}{N_{total\ files}} \times 100\%$	*68.7%*	65.2%	46.1%	39.1%	24.3%	20.9%	47.8%	29.6%	19.1%

3.4.1 Forest Habitats and Ecosystem Services

I identified four subcomponents in the Forest Habitats and Ecosystem Services category: *Soil*, *Vegetation*, *Animal Displacement*, and *Death of Invertebrates and Microorganisms.* About 39% (N = 53) of the articles emphasised *Soil*, 28% [N(Files) = 45] focused on *Vegetation*, 18% [N(Files = 28)] had *Vertebrate* as the primary subject of discussion and the remaining 15% [N(Files = 24)] had *Invertebrate and Microorganisms* as the central point of discussion.

3.4.1.1 Soil

Crude oil spills cause soil degradation. Soil degradation measures the physical, chemical and biological deterioration of soil quality. This phenomenon can involve soil salinity, fertility, acidity, soil structure, and soil contamination (NSW Government, 2019). Soil degradation is commonly experienced in the Niger Delta region due to crude oil exploratory activities, which is mainly attributed to continued gas flaring, dredging, drilling activities, and contamination of mangrove sediments from oil spills (Numbere, 2019; Oriaku et al., 2017; Agbonifo, 2016). Gases are flared to prevent the risk of exploration from mixtures of reactive gases during crude oil production (Miller, 2016). However, they introduce oxides of carbon, nitrogen, and sulphur, as well as particulate matter into the environment (Omeire et al., 2014).

Gas flaring affects soil temperature, pH, moisture content, bulk density, organic matter, and microbial population (Chukwuka et al., 2018; Uwagbae et al., 2014; Seiyaboh & Izah, 2017; Onwurah et al., 2007; Ohanmu et al., 2018). Increase in soil temperature causes about 60% decrease in the microbial load of soil (Chukwuka et al., 2018). This affects other properties of the soil, such as soil nutrients (e.g., P, K, and Na), leading to a reduction in soil fertility, which then leads to stunted growth (decreased plant height, decreased root length, and reduced salt exchange efficiency) (Ubogu & Odokuma, 2019; Onyena & Sam, 2020). From the literature coverage of the *Soil* component, there is an inverse relationship between the distance of gas flaring sites and soil properties, such as bulk density and temperature (Seiyaboh & Izah, 2017). On the contrary, a direct relationship occurs between gas flaring sites and properties such as organic matter and moisture content.

Soil compaction (which occurs when soil particles stick together) is usually formed during and after oil exploration (Onyena & Sam, 2020). It could also be caused by pedestrian traffic in oil fields (Chukwuka et al., 2018). The formation of soil compaction affects soil structure, causing other problems, such as soil fragmentation, decreased porosity and aeration, and decreased infiltration ability (Agbagwa and Ndukwu, 2014). This condition reduces the ability of plants to absorb water, distorts plant root structure and overall plant physiology (Chukwuka et al., 2018). This translates to stunted leaf development, and photosynthesis. As a result, mineral absorption efficiency is reduced, hindering the germination of seedlings, and ultimately causing the death of plants (Chukwuka et al., 2018). Furthermore, it has been speculated that noise generated from drilling sites could adversely impact plant growth at varying degrees (Kadafa, 2012b; Eluozo, 2018). In addition, dredging activities could change soil quality and prevent mangroves from growing (Numbere, 2019; Nwozor et al., 2019). The laying of pipelines in Eagle Island in the Niger Delta exemplifies the impact of dredging on mangrove forests (Numbere, 2019). This exposed the mangrove forests to invasive plant species such as Nypa palms at the expense of native plant species. This is why these palms blossomed better than native mangrove seedlings when planted on mangrove soils (Numbere, 2019).

3.4.1.2 Vegetation

The Niger Delta region is characterised by loss of natural vegetation due to large-scale dispersal of crude oil (Badejo & Nwilo, 2004). Mangrove vegetation close to gas flaring sites are susceptible to heat generated from the flare. Continuous gas flaring leads to build up of acid rain that causes defoliation of mangroves, tissue damage to aerial shoots, reduction in litter fall (Eboh, 2019; Mogaji et al., 2018; Omamoke & Achi, 2012). Mangrove plants are also negatively affected because the seedlings hardly survive when exposed to crude oil. Crude oil deposits from oil fields also damage the mangrove vegetation by coating aerial and submerged roots, hence making absorption difficult for them (Onyena & Sam, 2020). Moreover, crude oil droplets coat the breathing surfaces of the roots, stem and seedling, hindering salt exchange (Onyena & Sam, 2020; Zhang et al., 2019). On a broader scale, indiscriminate discharge of crude oil affects the mangrove vegetation's physiology, and anatomy (Chukwuka et al., 2018). For instance, the mangrove forest experiences mutagenesis when they come in contact with crude oil derivatives, such as PAHs (Chukwuka et al., 2018). The condition affects the chlorophyll-synthesising ability of the plant and foliar micro-structure of the leaves. Overall, exposing crude oil to natural vegetation causes deforestation, and biodiversity loss (Onyena & Sam, 2020; Ramirez et al., 2017).

The economical implication of losing vegetation to crude oil spills is not far-fetched. One of the economic values of the mangrove ecosystem is the provision of traditional medicine (Omeire et al., 2014). The quality of medicinal plants that can be used as phytotherapeutics is affected by change in its biochemical composition, thus, changing the plant's natural resilient property against pollutants (Shu et al., 2019). Example of widespread disposal of crude oil across vegetation was witnessed in Ogada-Brass pipelines splitter near Etiama Nembe in 1995 (Mogaji et al., 2018). Around 24,000 barrels of crude oil were dispersed across freshwater rainforests and mangrove swamp forests. Another notable oil spill occurred in 1998 at Eket, Akwa Ibom State, Niger Delta, Nigeria (Mogaji et al., 2018). About 40,000 barrels of crude oil caused the damage of 340 hectares of mangrove forests in the area. In addition, the replacement of vegetation by grasses and shrubs in many parts of the Niger Delta is a sign of loss of natural forest.

3.4.1.3 Terrestrial Vertebrates

The Niger Delta of Southern Nigeria is blessed with many faunal and floral groups. Endemic monkey taxa such as *Cercopithecus sclateri* and *Procolobus badius epieni* have been discovered in the region (Law, 2004). Other endemic species occur in this region. A typical example of such subspecies is the Niger Delta or Heslop's pygmy hippopotamus (*Hexaprotodon liberiensis heslopi*) (Luiselli et al., 2015; WWF, n.d.). The Niger Delta red Colobus (*Procolobus badius epieni*) is perceived to be one of the most discussed species that are under serious threat of extinction due to unfavourable conditions of the forest ecosystem in the region (Murphy, 2020). This is most occasioned by the loss of forest and mangrove habitat due to anthropogenic activities including those of crude oil companies. Most oil processing installations are usually situated inside rainforest and mangrove patches. The red colobus was first recorded in 1993 but it is now among the list of 25 most endangered primates by the International Union of Conservation of Nature (IUCN). Over the years, this species has progressively decreased its distance of existence from 1500 square kilometers to 78 square kilometers for most forests in Bayelsa state, Niger Delta, Nigeria. This distance range is on par with those of other primates such as the red-capped mangabey (*Cercocebus torquatus*), the Nigerian white-throated guenon (*Cercopithecus erythrogaster*, prococki) and mona monkey (*Cercopithecus mona*) (Orji, 2020). In fact, the population of the red colobus has dwindled over time from about 10,000 to around 5000 as of 2020 (Orji, 2020).

The Niger Delta red colobus lives most of its life on a particular tree species called *Hallea ciliata* and is locally known as “abura”. These trees are an important source of food to the Niger Delta red colobus. They also depend on young leaves of plants, such as *Lecomtedoxa klaineana* and *Xylopia aethiopica* for their survival (Usongo & Amubode, 2001). However, recent expansion of farming activities, bush burning resulting from oil pollution in the region have nearly wiped out these tree species. Hence, the red colobus is unable to survive since they are now deprived of their sources of food. Other mangrove fauna that are also affected by crude oil pollution are birds. When birds are in a mangrove habitat polluted with crude oil, they become less active because their wings are soaked by crude oil and as a result, they easily get exhausted when flying (International Bird Rescue, n.d.). Hence, other activities such as feeding, are affected. Also, drinking oil-polluted water also leads to the ingestion of oil into their body system which damages their guts, consequently, leads to poisoning, starvation and death (King et al., 2020). The recurrence of oil pollution eventually leads to the reduction in bird population within the Niger Delta.

3.4.1.4 Terrestrial Invertebrates

Most studies have been on the impact of oil pollution on terrestrial vertebrates, however, there has been a limited number of studies focusing on terrestrial invertebrates. Despite this, terrestrial invertebrates are an indispensable component of an ecosystem. They play important roles in providing ecosystem services and are also pivotal in the food web (Morley et al., 2013). In addition, they provide food to both terrestrial and marine vertebrates as well as humans, apart from the roles they play in decomposing organic matter to improve soil fertility (Barthod et al., 2020). Terrestrial invertebrates such as arthropods, which represent a major component of the biodiversity of the salt marshes, are sensitive to oil pollution (Pennings et al., 2014). Oil pollution potentially has a long-lasting effect on these organisms. Studies to corroborate this claim have been carried out in Niger Delta communities impacted by crude oil spills. For instance, recent studies showed that the crude oil spills affect the biodiversity and abundance of soil arthropods and soil mesofauna (such as earthworms, arthropods, nematodes, and mollusks) because exposure of these species to oil spillages reduces their composition, especially for regions recently contaminated with crude oil (Adeduntan & Owokotomo, 2018, Rotimi et al., 2014). Remediated crude-polluted localities expectedly have more species in abundance and diversity than recently short-term polluted localities (Rotimi et al., 2014, Uwagbae et al., 2014). This suggests that the period and age of oil pollution also reflects the species' biodiversity, richness, and abundance.

3.4.2 Agricultural Productivity

Query results from the *Agricultural Productivity* component yields *Crop Yield* and *Food Quality* subcomponents. The *Crop Yield* subcomponent makes up 61% [N(Files) = 34] of the files obtained and the *Food Quality* subcomponent makes up 39% [N(Files) = 22].

3.4.2.1 Crop Yield

Soil degradation also has adverse consequences on the volume of crop yield and survival of plants. From the reviewed literature, it was observed that most cases of reduced crop yields were directly linked to the increase in greenhouse gases (Omeire et al., 2014). In the Niger Delta region, plantations located close to gas flaring sites are affected by the emission of greenhouse gases from these sites (Seiyaboh & Izah, 2017). Gas flaring contributes to global climate change which breeds pests, causes spread of diseases, flooding, coastal erosion and inconsistent rainfall patterns (Omeire et al., 2014; Ifeanyieze et al., 2016). Gas flaring increases greenhouse gases thereby contributing to global warming and climate change in the region (Omeire et al., 2014). Climate change breeds pests, spread of diseases, flooding, coastal erosion and inconsistent rainfall patterns (Ifeanyieze et al., 2016). This ultimately leads to crop failure, affecting the volume of harvested crops. As an example, in the Niger Delta region, farmers have to religiously maximize the rainfall pattern of the seasons. As a result, farmers who plant after the first or second rain in the June/July season (the peak season) usually run into massive loss whenever the rains are delayed beyond the expected period due to climate change (Uyigue & Agbo, 2007; Ifeanyieze et al., 2016). Gas flaring affects a wide spectrum of food and cash crops. For instance, it decreases the length and weight of cassava, and its amino acid and sugar content due to high temperatures around gas flaring sites (Ordinioha & Brisibe, 2013; Seiyaboh & Izah, 2017). This observation was found to be more conspicuous with cassava plantations close to gas flaring sites (Dung et al., 2008). Other food crops that are also affected are yam, okra, plantain, maize and potatoes (Seiyaboh & Izah, 2017; Chukwuka et al., 2018).

3.4.2.2 Food Quality

Crude oil production activities, such as gas flaring and crude oil spill remediation, potentially change the nutritional composition of foods. For example, the composition of anti-nutrients (such as alkaloids, cyanogenic glycosides, and tannin) present in common edible vegetables (e.g., bitter leaf, water leaf, and pumpkin leaf) changes due to exposure to the implications of gas flaring (Seiyaboh & Izah, 2017). Literature has also shown that ascorbic acid, a natural water-soluble vitamin (Vitamin C) antioxidant agent, significantly reduced in waterleaf and the protein content of cassava also reduced when these crops were exposed to oil spill (Seiyaboh & Izah, 2017; Abonyi, 2020). The quality of seafood from aquatic environments has also reduced due to the accumulation of PAHs (Ukpong & Obok, 2018). In addition, staple foods (such as cocoyam and cereals) that are routinely consumed in the Niger Delta region have lost their nutritional value

(Abonyi, 2020). This has brought about proliferation in childhood malnutrition in many Niger Delta communities (Ordinioha & Sawyer, 2008). Moreso, heavy metals (mainly lead and cadmium) have also been discovered in significant quantities in cassava and pumpkin leaves (Abonyi, 2020). These poisonous elements further compromise the quality of staple foods consumed in the Niger Delta.

Chapter 4 : Discussion

4.1 Comparative Analysis of Components that are Impacted by Oil Spills

4.1.1 Layer Three (3) Factors

Based on the results of the systematic review, sixteen (16) layer-3 factors (Figure 3.5) were identified to be impacted by oil spills in the Niger Delta. However, the relative numbers of articles that appeared to show interest in these factors differ. For the sake of simplicity, a bar chart shown in Figure 4.1, has been used to describe the volume of articles (in terms of the percentage probability) that was acquired based on the sample space (the 115 articles harvested using the PRISMA approach). From Figure 4.1, the most studied factors that are impacted by oil spills are *Soil* (46.1%), *Vegetation* (39.1%), *Aquatic Vertebrates* (40.9%) and *Consumption Patterns* (35.7%), while the least studied factors are *Human Displacement* (13.9%), *Human Exposure* (19.1%), *Conflicts* (14.8%), *Terrestrial Invertebrates* (20.9%), *Terrestrial Vertebrates* (24.3%), *Food Quality* (19.1%), and *Aquatic Invertebrates* (20.9%). *Terrestrial Invertebrates* and *Aquatic Invertebrates* appear to show equal importance. The same can be said of *Human exposure* and *Food Quality*. I presume that these two factors (*Human exposure* and *food quality*) cannot be completely controlled because they are contingent upon the degree of oil pollution in the Niger Delta region. Despite the fact that we desire to always lower the level of our exposure to crude oil pollutants and improve our food quality, we cannot do without living in our environment and consuming foods that are at our disposal if we do not achieve our desires.

The percentage probability of the *Human Displacement* factor showed that it has not been the nexus of research relating to oil pollution in Niger Delta. That is to say that only a handful of researchers have explored the effects of oil pollution on human displacement with reference to the sample space. This can potentially be attributed to the fact that almost every major oil producing

Niger Delta communities are facing this challenge. Hence, it is a widespread problem that seems to have been entrenched in the everyday life of the Niger Delta people. This could have made it not a commonly discussed issue.

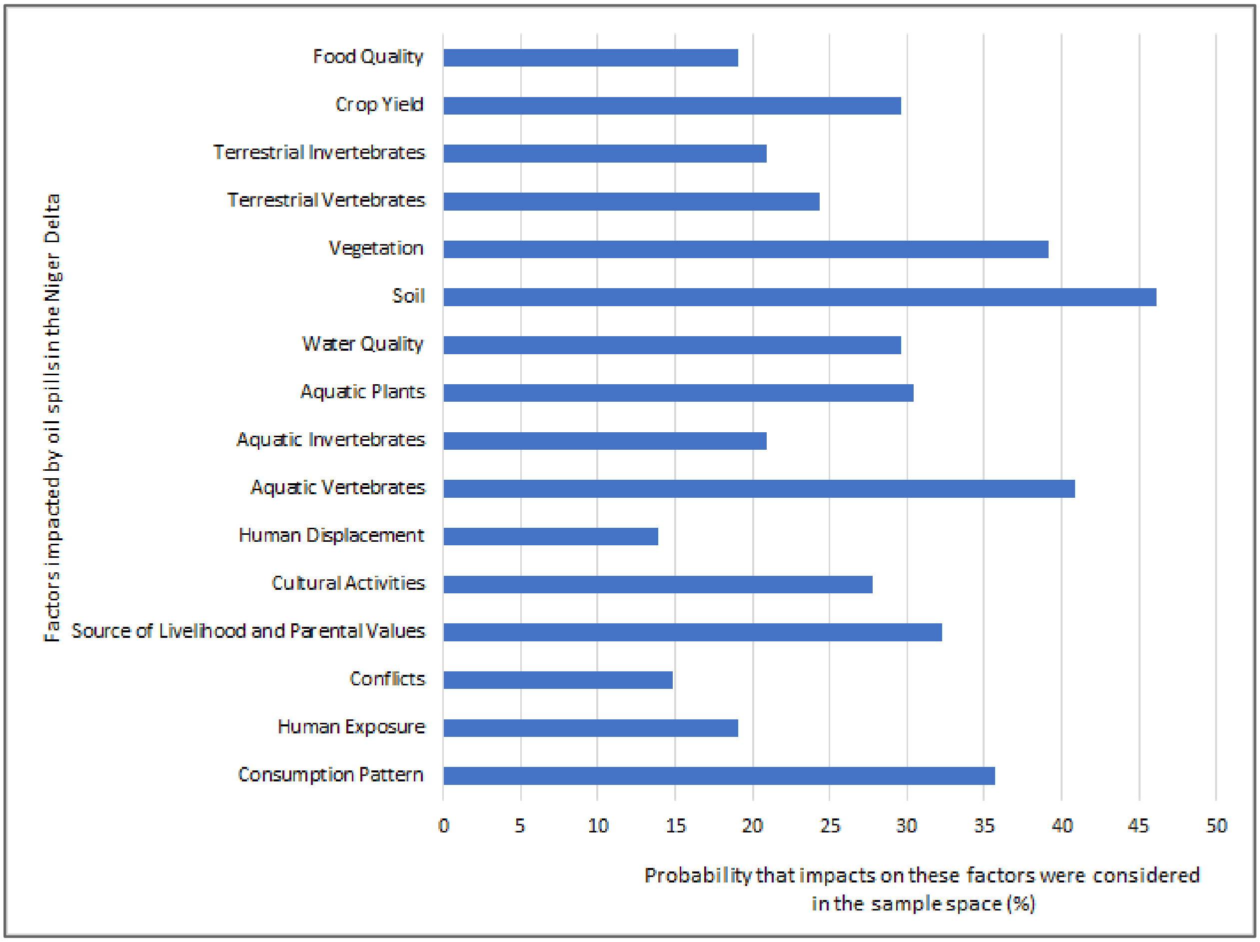

Figure 4.1: Comparative percentage probabilities that the impacts of crude oil (identified in Layer 3 of Figure 3.5) were considered by authors in the articles given the sample space (all the 115 articles harvested using the PRISMA approach)

Impacts of oil spill in the Niger Delta region as it relates to conflicts in the region was amongst the least discussed component from the literature. Few authors indicated that most of the clashes between different agitation groups must have been instigated by the connivance between leaders of the Niger Delta communities and multinational oil companies. Other authors opinionated that most of the inter- and intra-communal clashes in the region were caused by disagreements in the process of royalty interests. Hence, there are contrary opinions as to the major instigators of conflicts in the region. The speaks volumes about the complexity of the politics surrounding oil exploration and production in the Niger Delta. Furthermore, I conjecture that the frequency and full details of the occurrence of conflicts in the region have been ill-reported and downplayed by the media from the outset of these incidents.

Terrestrial Vertebrates and *Terrestrial Invertebrates* are little discussed in the literature. In the review of the *Terrestrial Vertebrates* subcomponent, some vertebrates were identified namely, *Cercopithecus sclateri*, *Procolobus badius pieni* (the red colobus), *Heslop's pygmy hippopotamus*, *Cercocebus torquatus*, *Cercopithecus erythrogaster* and *Cercopithecus mona.* Nevertheless, there is still paucity of information about these vertebrates and many other vertebrates in this region that have already gone into extinction. There are also limited studies on terrestrial invertebrates despite their contribution to the general ecosystem of the region. For instance, earthworms break down organic matter and fertilize the soil. Other invertebrates, such as arthropods, and nematodes, also have their economic benefits. Regrettably, the reviewed articles have shown that it is difficult to quantify the population of these invertebrates affected by crude oil spills.

4.1.2 Layer Two (2) Factors

From Layer 2 of Figure 3.5, six (6) factors were identified to be impacted by oil spills in the Niger Delta. Figure 3.8 fleshes out these factors with respect to the probability that the impact of oil spills on these factors were considered considerably by authors drawn from the sample space. In Figure 4.2, impacts on *Forest Habitats and Ecosystem Services* (47.8%) were mostly discussed by authors, while impacts on *Water* were the least discussed (39.1%). It can also be observed from the figure that the *Human Health and Mortality Rate* component closes in on *Forest Habitat and Ecosystem Services*. This suggests that both components share almost equal significance within the Niger Delta ecosystem, confirming that survival of locals in the Niger Delta region can possibly be measured by the amount of ecosystem services being provided by the forest habitats; and human health and mortality rates.

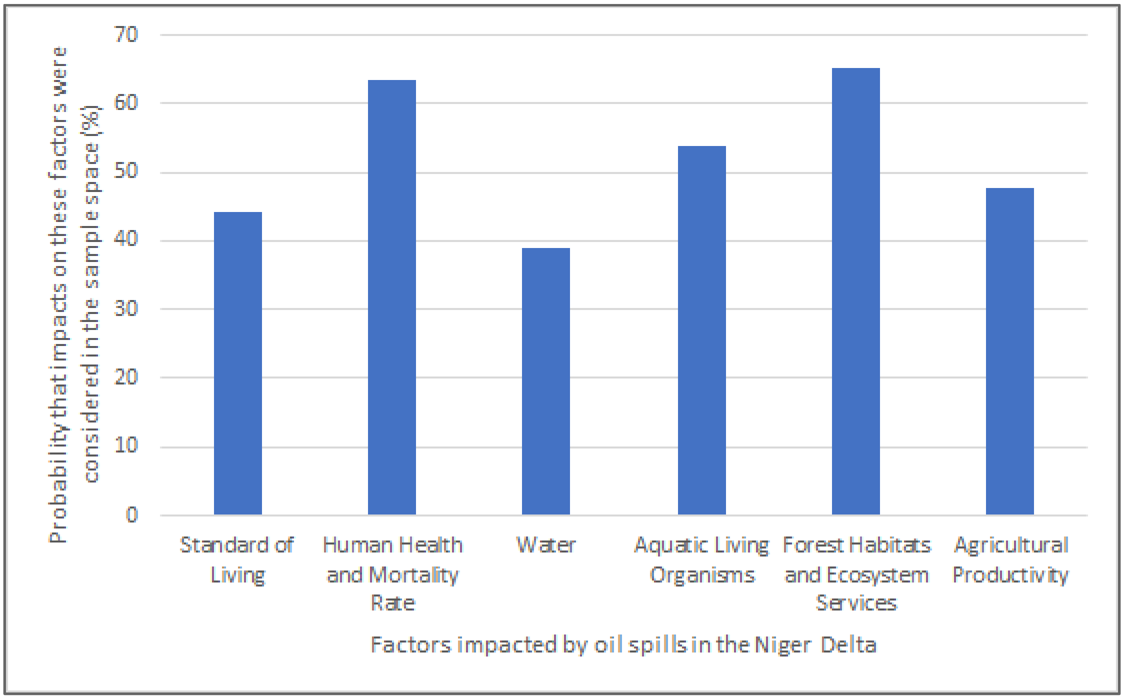

Figure 4.2: Comparative percentage probabilities that the impacts of crude oil (identified in Layer 2 of Figure 3.5) were considered by authors in the articles given the sample space (all the 115 articles harvested using the PRISMA approach)

4.1.3 Layer One (1) Factors

At Layer 1 (Figure 3.5), the three major components impacted by crude oil spills in the Niger Delta are *Humans*, *Aquatic Environment*, and *Terrestrial Environment*. Figure 4.3, compared the percentage probabilities that the impacts on these three factors were discussed by authors in their research (drawn from the sample space). The impact on the *Humans* component, which has a percentage probability of 76.5%, was discussed by most authors relative to the sample space. Equal percentage probability (68.7%) was recorded for *Aquatic Environment* and *Terrestrial Environment* components. It can, thus, be implied that impacts of oil spills on *Humans* were mostly considered by authors drawn from the sample space. I also conjecture that most authors who discussed impacts on *Aquatic Environment* equally discussed impacts on *Terrestrial Environment*. This suggests that there could be relative paucity of information/studies about the Niger Delta aquatic environment and terrestrial environment and how oil spills have impacted them.

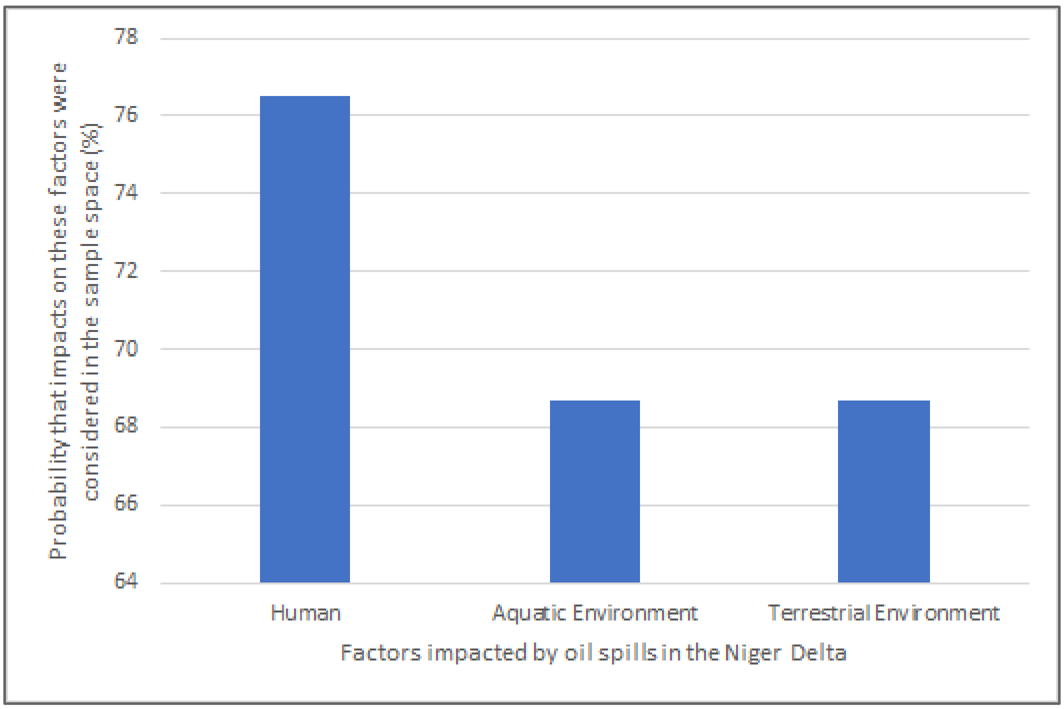

Figure 4.3: Comparative percentage probabilities that the impacts of crude oil (identified in Layer 1 of Figure 3.5) were considered by authors in the articles given the sample space (all the 115 articles harvested using the PRISMA approach)

Finally, the review has shown that the magnitude of the discussions on the impact of crude oil spills is incomparable with those linked to the impacts of gas flaring in the Niger Delta region. Gas flaring appears to be a major concern and has a far-reaching effect on subcomponents mainly, *vegetation, human displacement, human exposure, soil, crop yield and food quality*. This implies that about 37.5% of the third-layer articles from the sample space are influenced by gas flaring in oil fields. Although gas flaring exuded unstable gaseous components during crude oil production, the emission of these gases should be controlled as it has a long-term effect on the subcomponents previously mentioned. This is not to say that spilled oil does not degrade the environment. However, flared gas can travel much longer distances and could devastate a wider area within a city or community. Worst still, one of the long-term effects of gas flaring that the world is currently battling with is climate change. Hence, gas flaring should be regulated by relevant authorities.

4.2 Limitations of the Research

1. Due to the method used, the results of this research are limited to the articles reviewed for the entire research.
2. All the articles reviewed may not fully show the impacts of oil pollution on Niger Delta ecosystem. So, this review process only serves as a guide which can further be expanded upon.

4.3 Framework for Measuring the Impacts of Oil Spill on the Niger Delta Ecosystem

The impacts of oil pollution on Niger Delta ecosystem components have been identified. Each component had subcomponents that lead to the major factors that are impacted by oil pollution. A total of sixteen (16) components/factors were identified from the articles with the impacts of crude oil pollution on these factors. In order to establish a roadmap that better equip environmentalists and researchers in quantifying and measuring the impacts of crude oil exploration on the Niger Delta ecosystem, a framework that underscores these impacts has been laid out in Figure 4.4.

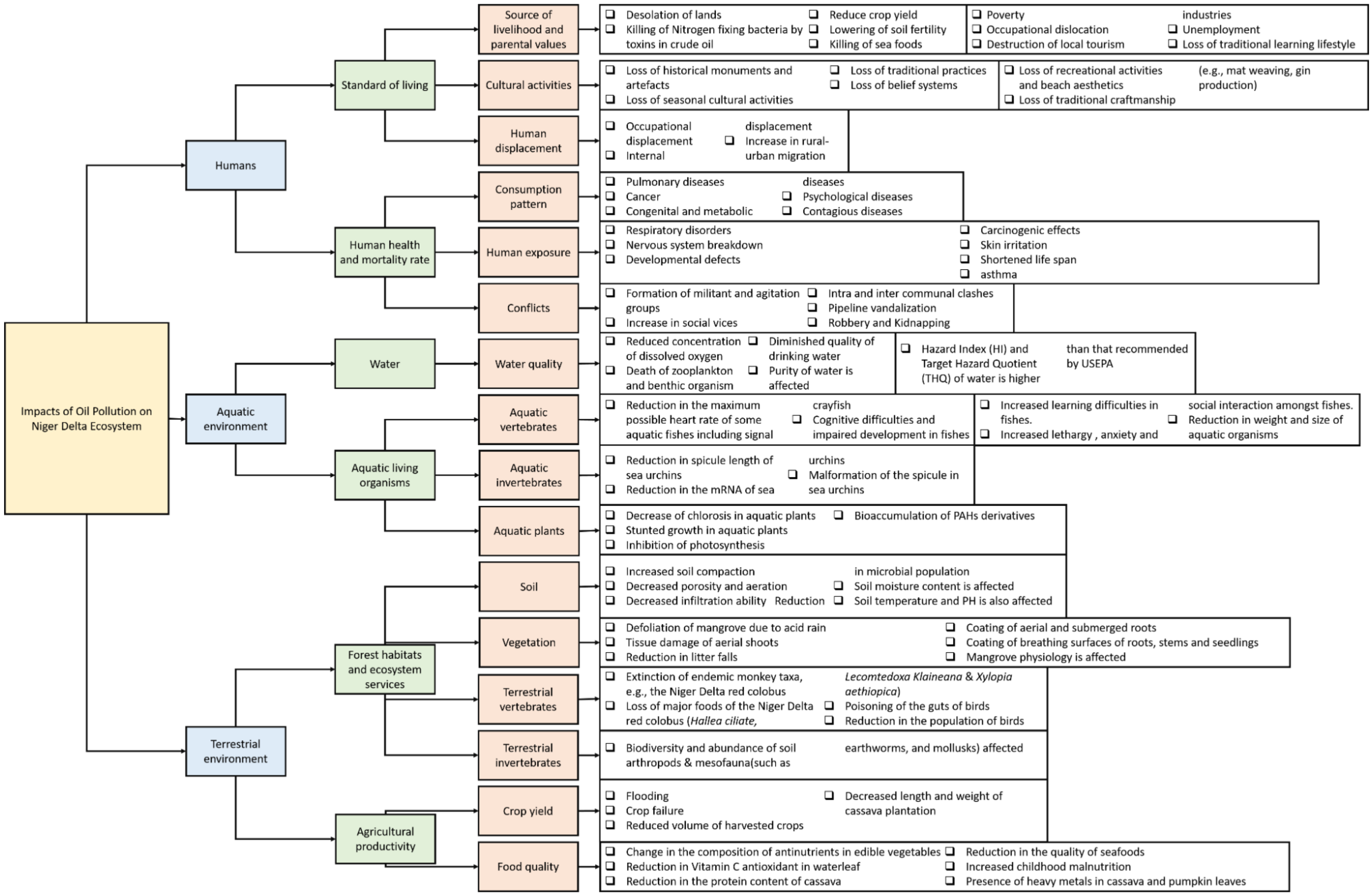

Figure 4.4: Research framework for measuring the impacts of oil spill on Niger Delta ecosystems

Chapter 5 : Conclusions and Recommendations

5.1 Conclusions

The primary motivation of this study is the problem of pollution due to crude oil on the entire ecosystems in Niger Delta, Nigeria. Several articles were investigated in this study using NVivo software. A total of 250 articles were searched out from various resources out of which 115 were used for data extraction. Querying the articles that met the inclusion criteria of this research yielded several keywords, which were further classified into three major components, followed by detailed coding. These components are *Humans, Aquatic Environments and Terrestrial Environment*. Results from exploring all codes derived from the three components showed that the impacts of oil pollution on sustenance and livelihoods of humans appeared to be majorly discussed by all the authors as buttressed by the word frequency diagram shown in Figure 5.1.

Figure 5.1: Word frequency diagram accentuating the importance of livelihood sustenance in the Niger Delta region of Nigeria

5.2 Recommendations

Results from the document analysis emphasized the highly significant effect of crude oil spills on livelihoods and sustenance. Insufficient research information about some Niger Delta ecosystem components was the major research gap identified in the systematic review conducted. As a result, to further consolidate the body of knowledge on the various impacts of oil spills on the Niger Delta ecosystem, the following recommendations are made:

- Studies on the impacts of oil spills on humans should not be isolated because other ecosystem components, mainly aquatic and terrestrial environments, determine the survival of humans. Hence, environmentalists and researchers alike should equally extensively do more research about different species of organisms that live in these environments and how oil pollution impact their existence and survival
- While we wait for the remediation of the Niger Delta environment, factors such as *human exposure* and *food quality,* which provide information about the level of environmental exposure to oil pollution and the quality of food consumed, cannot be totally controlled. Hence, healthcare facilities and services should be established adequately in order to control any health challenge when the need arises
- Researchers should also harvest information about human displacement in the Niger Delta region of Nigeria. This will provide more insight about the population of people migrating from one community to another in search of arable agricultural lands or better job opportunities. This information can be used to create a mathematical model when correlated with the degree of oil pollution in the community, contributing to the body of knowledge of environmental sciences.

- Scientists and environmentalists should seek to explore Niger Delta aquatic and terrestrial invertebrates as there are not so many studies that show the abundance of these species in the region.

Niger Delta stakeholders should also provide a remediation formula that will prevent the complete collapse of the already-threatened Niger Delta environment. The following recommendations can be adopted by all Niger Delta stakeholders, including the Federal Government of Nigeria and Multinationals.

- Multinational oil firms should initiate a planned routine maintenance of the oil installations and pipelines. This is because most pipelines which have been functioning for decades without being routinely maintained have developed leakages due to natural phenomena, such as corrosion and acid rain, facilitating oil spillage over a wide range of pipeline networks. Thus, replacing this oil pipeline infrastructure will significantly cut down oil spills in the region;
- Community leaders, multinational oil firms and the Federal Government of Nigeria should collectively relocate gas flaring sites (which is a major concern) and commence scheduled cleaning of regions already contaminated with crude oil. This should be immediately followed by a campaign directed at empowering young people to embrace agriculture by providing long-term loans and grants in order to not only revive the region's agricultural prowess but also deter rural-urban migration.
- Green farming should temporarily replace non-existent farmlands during the remediation of the Niger Delta environment. In addition, animals at high-risk of extinction should be protected until their environment has been certified safe for inhabiting.

- Most Niger Delta regions that have been struggling with oil pollution are usually not fortified with social amenities, such as reliable healthcare and good public schools. Hence rural people who reside in these areas are vulnerable. As a result, the Nigerian Government and executive of oil companies should collaborate to ensure that rural people have access to reliable healthcare and education.
- Multinationals should be more accountable than ever in issues regarding oil pollution and environmental degradation; and
- Rural education curricula that contain subjects on environmental conservation should be added to the early childhood education framework

References

Abah, R. C. (2013). Vulnerability of Fisheries Livelihood in the Coastal Area of the Niger Delta Region of Nigeria. World Journal of Fish and Marine Sciences, *5*(2), 152-158.

Abonyi, N. N. (2020). Environmental pollution and associated health hazards to host communities (Case study: Niger delta region of Nigeria). Central Asian Journal of Environmental Science and Innovation, *1*(2020), 30-42. https://doi.org/10.22034/CAJESTI.2020.01.04

Adeduntan, S. A., & Owokotomo, O. O. (2018). Effect of oil spillage on abundance and biodiversity of soil mesofauna in Bodo City, Niger Delta, Nigeria. *The Journal of the Society of Tropical Plant Research*, *5*(2), 260-266

Adekola, J., Fischbacher-Smith, M., Fischbacher-Smith, D., & Adekola, O. (2017). Health risks from environmental degradation in the Niger Delta, Nigeria. *Environment and Planning: Politics and Space*, *35*(2), 334–354. https://doi.org/10.1177/0263774X16661720

Adeyeye, S. A. O. (2020). Polycyclic Aromatic Hydrocarbons in Foods: A Critical Review. Current Nutrition & Food Science, *16*(6), 866-873, https://doi.org/10.2174/1573401315666190215112216

Agbagwa, I. O. & Ekeke, C. (2011). Structure and Phytodiversity of Freshwater Swamp Forest in Oil-rich Bonny, Rivers State, Nigeria. *Research Journal of Forestry*, *5*(2), 66-77. https://doi.org/10.3923/rjf.2011.66.77

Agbagwa, I. O., & Ndukwu, B. C. (2014). Oil and Gas Pipeline Construction-Induced Forest Fragmentation and Biodiversity Loss in the Niger Delta, Nigeria. Natural Resources, *5*, 698-718. http://dx.doi.org/10.4236/nr.2014.512061

Agbonifo, P. (2016). Oil spills injustices in the Niger Delta region: reflections on oil industry failure in relation to the United Nations Environment Programme (UNEP) report. *International Journal of Petroleum and Gas Exploration Management*, *2*(1), 26-37

Ainerua, M. O., Tinwell, J., Murphy, R., Galli, G. L. J., van Dongen, B. E., White, K. N., & Shiels, H. A. (2020). Prolonged phenanthrene exposure reduces cardiac function but fails to mount a significant oxidative stress response in the signal crayfish (Pacifastacus leniusculus). *Chemosphere*, *268*, 129297. https://doi.org/10.1016/j.chemosphere.2020.129297

Akinro, A. O., Opeyemi, D. A., & Ologunagba, I. B. (2008). Climate Change and Environmental Degradation in the Niger Delta Region of Nigeria: Its Vulnerability, Impacts and Possible Mitigations. *Research Journal of Applied Sciences*, *3*(3), 167-173

Akinwumiju, A. S., Adelodun, A. A., & Ogundeji, S. E. (2020). Geospatial assessment of oil spill pollution in the Niger Delta of Nigeria: An evidence-based evaluation of causes and potential remedies. *Environmental Pollution*, *267*, 115545. https://doi.org/10.1016/j.envpol.2020.115545

Akpofure, E. A., Efere, M. L., & Prosper, A. (2000). Integrated grass root post impact assessment of acute damaging effects of continuous oil spills in the Niger Delta. A paper report on oil spillage in the Niger Delta

Akpokodje, J., & Salau, S. (2015). Oil Pollution and Agricultural Productivity in the Niger Delta of Nigeria. *Environmental Economics*, *6*(4), 68-75. Retrieved from https://www.businessperspectives.org/images/pdf/applications/publishing/templates/article/assets/7056/ee_2015_04_Akpokodje.pdf

Albert, O. N., Amaratungaa, D. & Haigha, R. P. (2017, November 27 -29). *Evaluation of the impacts of oil spill disaster on communities and its influence on restiveness in Niger Delta, Nigeria* [paper presentation]. 7th International Conference on Building Resilience; Using scientific knowledge to inform policy and practice in disaster risk reduction, ICBR201, Bangkok, Thailand

Alongi, D. M. (2014). Carbon Sequestration in Mangrove Forests. *Carbon Management*, *3*(2), 313-322. https://doi.org/10.4155/cmt.12.20

Amadi, A. N. (2014). Impact of Gas-Flaring on the Quality of RainWater, Groundwater and Surface Water in Parts of Eastern Niger Delta, Nigeria. *Journal of Geosciences and Geomatics*, *2*(3), 114-119. https://doi.org/10.12691/jgg-2-3-6

Amnesty International. (2018). Negligence in the Niger Delta: Decoding Shell and Eni's Poor Records on Oil Spills. Retrieved August 6, 2021, from https://www.amnesty.org/download/Documents/AFR4479702018ENGLISH.PDF

Amnesty International. (2009). Nigeria: Petroleum, Pollution and Poverty in the Niger Delta. Retrieved July 30, 2021 from https://www.refworld.org/pdfid/4a4a1dfc2.pdf

Ana, G. R. (2011). Air Pollution in the Niger Delta Area: Scope, Challenges and Remedies. In M. Khallaf (Eds.). *The Impact of Air Pollution on Health, Economy, Environment and Agricultural Sources*. https://doi.org/10.5772/16817

Anyanwu, C. I., & Ejem, E. A. (2020). Analysis of Variables of Maritime-induced Oil Spillage in Niger Delta Region of Nigeria. *British Journal of Environmental Sciences*, *8*(4), 1-8. Retrieved from https://www.eajournals.org/journals/british-journal-of-environmental-sciences-bjes/vol-8-issue-4-december-2020/analysis-of-variables-of-maritime-induced-oil-spillage-in-niger-delta-region-of-nigeria/

Arugu, L. O. (2015). The Agricultural Sector and Labour Output in The Niger Delta. *Department of Political Science, Federal University, Otuoke, Bayelsa State.*

Arimoro, F. O., Ikomi, R. B., Ajuzieogu, I. O. & Nwadukwe, F. O. (2011). Temporal and spatial variability in macroinvertebrate community structure in relation to environmental variables in Ajijiguan Creek, Niger Delta, Nigeria. *African Journal of Aquatic Science*, *36*(1), 57-66. https://doi.org/10.2989/16085914.2011.559687

Ayanlade, A. (2014). *Remote Sensing of Environmental Change in the Niger Delta, Nigeria*. [Doctoral dissertation, King's College London]. Open collections https://kclpure.kcl.ac.uk/portal/files/45172782/2015_Ayanlade_Ayansina_0854358_ethesis.pdf

Ayanlade, A., & Drake, N. (2015). Forest loss in different ecological zones of the Niger Delta, Nigeria: evidence from remote sensing. *GeoJournal*, 81, 717-735

Ayanlade, A. & Howard, M. T. (2016) Environmental impacts of oil production in the Niger Delta: remote sensing and social survey examination. *African Geographical Review*, *35*(3), 272-293. https://doi.org/10.1080/19376812.2016.1209121

Baba, I., Mahdi, M. A., Adamu, I. G., & Kachallah, A. M. (2020). Oil Politics and Related Conflict in Nigeria's Niger-Delta; Cause and Impact on Ogoni Land and People. *IAR Journal of Humanities and Social Science, 1*(1), 11-24

Baali, A., Kammann, U., Hanel, R., El Qoraychy, I., & Yahyaoui, A. (2016). Bile metabolites of polycyclic aromatic hydrocarbons (PAHs) in three species of fish from Morocco. *Environmental Sciences Europe*, *28*(1). https://doi.org/10.1186/s12302-016-0093-6

Babatunde, A. (2020). Local perspectives on food security in Nigeria's Niger delta. *The Extractive Industries and Society, 7*(3), 931-939. https://doi.org/10.1016/j.exis.2020.07.011

Bada, O. (2018). Freshwater swamp forests-forest types around the world. Retrieved July 25, 2021, from https://www.worldatlas.com/articles/what-is-a-freshwater-swamp-forest.html

Badejo, O. T., & Nwilo, P. C. (2004). Management of oil spill dispersal along the Nigerian coastal areas. Retrieved June 21, 2021, from https://www.isprs.org/proceedings/XXXV/congress/comm7/papers/241.pdf

Barthod, J., Dignac, M. -F., Le Mer, G., Bottinelli, N., Watteau, F., Kögel-Knabner, I., & Rumpel, C. (2020). How do earthworms affect organic matter decomposition in the presence of clay-sized minerals?. *Soil Biology and Biochemistry, 143,* https://doi.org/10.1016/j.soilbio.2020.107730

Braide, A. S., Adegoke, O. A., & Bamigbowu, E. O. (2011). Effect of Cassava based diet on hepatic proteins in albino rats fed with crude oil contaminated diet. *Journal of Applied Sciences and Environmental Management*, 15(1), 223-229. https://doi.org/10.4314/jasem.v15i1.65703

Brette, F., Shiels, H., Galli, G., Cros, C., Incardona, J. P., Scholz, N. L., & Block, B. A.(2017). A Novel Cardiotoxic Mechanism for a Pervasive Global Pollutant. *Scientific Reports, 7*, 41476. https://doi.org/10.1038/srep41476

Carugati, L., Gatto, B., Rastelli, E., Martire, M. L., Coral, C., Greco, S., & Danovaro, R. (2018). Impact of mangrove forests degradation on biodiversity and ecosystem functioning. *Scientific Reports, 2018*(8), 1-11, https://doi.org/10.1038/s41598-018-31683-0

Christou, D. D., Seals, D. R. (2008). Decreased maximal heart rate with aging is related to reduced -adrenergic responsiveness but is largely explained by a reduction in intrinsic heart rate. *Journal of Applied Physiology*, *105*(1), 24–29. http://doi.org/10.1152/japplphysiol.90401.2008

Chukwuka, K. S., Alimba1, C. G., Ataguba, G. A. & Jimoh, W. A. (2018). The Impacts of Petroleum Production on Terrestrial Fauna and Flora in the Oil-Producing Region of Nigeria. In P. E. Ndimele (Eds), *The Political Ecology of Oil and Gas Activities in the Nigerian Aquatic Ecosystem*. (pp. 125-142). Cambridge: Academic Press

IFRC (n.d). What is a livelihood?. Retrieved May 14, 2021, from https://www.ifrc.org/en/what-we-do/disaster-management/from-crisis-to-recovery/what-is-a-livelihood/

Daka, E. R., & Ugbomeh, A. P. (2013). Polycyclic Aromatic Hydrocarbons in Sediment and Tissues of the Crab Callinectes pallidus from the Azuabie Creek of the Upper Bonny Estuary in the Niger Delta. *Research Journal of Applied Sciences, Engineering and Technology*, *6*(14), 2594-2600. https://doi.org/10.19026/rjaset.6.3744

Dimkpa, C. H., Ebere, N. & Ugbomeh, A. P. (2019). Prevalence of Mosquitoes Harbouring Microfilariae in Four Communities in Andoni, Rivers State, Nigeria. *Asian Journal of Biological Sciences*, *12*(4), 851-859. https://doi.org/10.3923/ajbs.2019.851.859

Donato, D. C., Kauffman, J. B., Murdiyarso, D., Kurnianto, S., Stidham, M. & Kanninen, M. (2011). Mangroves among the most carbon-rich forests in the tropics. *Nature Geoscience*, *4*(5), 293–297. https://doi.org/10.1038/ngeo1123

Dung, E.J., Bombom, L.S. & Agusomu, T.D. (2008). The effects of gas flaring on crops in the Niger Delta, Nigeria. *GeoJournal* 73, 297–305. https://doi.org/10.1007/s10708-008-9207-z

Eboh, A. (2019). Crude Oil Exploration And Exploitation In Niger Delta: A Christian Concern. International Journal of Innovative Development and Policy Studies, *7*(2), 38-49. Retrieved from https://seahipaj.org/journals-ci/june-2019/IJIDPS/full/IJIDPS-J-5-2019.pdf

Eboh, M. (2020). Oil firms spill 3,346 barrels of crude oil in eight months--Investigation. Retrieved July 19, 2021, from https://www.vanguardngr.com/2020/09/oil-firms-spill-3346-barrels-of-crude-oil-in-eight-months-%E2%80%95-investigation/

Ekanem, J., & Nwachukwu, I. (2015). Sustainable Agricultural Production in Degraded Oil Producing and Conflict Prone Communities of Niger Delta, Nigeria. *Journal of Agriculture and Sustainability*, *8*(1), 14-28

Eleke, P. N., Jibril, M. & Nte, J. M. (2019). A Review of the Effect of Crude Oil Exploration on Agriculture: A Case Study of the Niger Delta Region. *Journal of Agricultural Economics, Environment and Social Sciences*, *5*(1&2), 87–98. Retrieved from http://www.jaeess.com.ng

Eluozo, C. (2018). Oil Exploration in the Niger Delta: Its' Gains and Loss. IIARD International Journal of Geography and Environmental Management, *4*(2), 24-31. Retrieved from www.iiardpub.org

Enegide, C., & Chukwuma, K. C. (2018). Oil Spillage and Heavy Metals Toxicity Risk in the Niger Delta, Nigeria. *Journal of Health and Pollution*, *8*(19), 1-8. https://doi.org/10.5696/2156-9614-8.19.180905

Enuoh, O. O., & Ogogo, A. U. (2018). Assessing Tropical Deforestation and Biodiversity Loss in the Cross River Rainforest of Nigeria. *Open Journal of Forestry*, 8, 393-408

Environmental Pollution Centers. (2021). Oil Spill Pollution Diseases. Retrieved April 28, 2021, from https://www.environmentalpollutioncenters.org/oil-spill/diseases/

Etuk, B. A., Udiong, D. S., & Akpakpan, A. E. (2020). Human Health Risk Management of Trace Metals in Water from Cross River Estuary, Niger Delta, Nigeria. *Asian Journal of Chemical Sciences*, *7*(3), 1-11. https://doi.org/10.9734/AJOCS/2020/v7i319020

Ewah-Oboho, I., Emile Asuquo, F., Emeh, J., & Oladimeji, S. (2005). Mangrove species distribution and composition, adaptive strategies and ecosystem services in the Niger River Delta, Nigeria. *Journal of Environmental Systems*, *32*(2), 145-172. https://doi.org/10.2190/ES.32.2.e

Ezenwaka, J. & Graves, A. (2014). Ecosystem Services of the Niger Delta Forests, Nigeria. *Journal of Agricultural and Social Research*, *14*(1), 37-56

Fan, S., Liu, H., Zheng, G., Wang, Y., Wang, S., Liu, Y., Liu, X., & Wan, Y. (2018). Differences in phytoaccumulation of organic pollutants in freshwater submerged and emergent plants. *Environmental Pollution*, *241*, 247–253. https:/doi.org/10.1016/j.envpol.2018.05.071

FAO. (2018, May 2-4). *Be the solution to soil pollution*. Proceedings on Global Symposium on Soil Pollution, FAO Headquarters, Rome, Italy.

Feka, N. Z., & Ajonina, G. N. (2011). Drivers causing decline of mangrove in West-Central Africa: a review. *International Journal of Biodiversity Science, Ecosystem Services & Management*, *7*(3), 217–230. https://doi.org/10.1080/21513732.2011.634436

Fern, K. (2014). Useful tropical plants. Retrieved July 24, 2021, from http://tropical.theferns.info/viewtropical.php?id=Triplochiton+scleroxylon

Fischer, G., Nachtergaele, F., Prieler, S., van Velthuizen, H. T., Verelst, L., & Wiberg, D. (2008). *Global Agro-ecological Zones Assessment for Agriculture (GAEZ 2008)*. IIASA, Laxenburg, Austria and FAO, Rome, Italy

Foli, S., Reed, J., Clendenning, J., Petrokofsky, G, Padoch, C., & Sunderland, T. (2015). To what extent does the presence of forests and trees contribute to food production in humid and dry forest landscapes? A systematic review protocol. *Center for International Forestry Research*, Working Paper 168. Bogor, Indonesia: CIFOR

Fund for Peace. (2016). Niger Delta Quarterly Conflict Trends. Retrieved July 24, 2021, from https://reliefweb.int/report/niger/niger-delta-quarterly-conflict-trends-july-september-2016

Gajula, H., Kumar, V., Vijendra, P. D., Rajashekar, J., Sannabommaji, T., & Basappa, G. (2020). *Secondary metabolites from mangrove plants and their biological activities. In Biotechnological Utilization of Mangrove Resources, 117–134.* doi:10.1016/b978-0-12-819532-1.00005-6

Glime, J. M. (2019). Tropics: Lowland Rainforests. In J. M. Glime (Eds) *Bryophyte Ecology: Habitat and Role*.Ebook sponsored by Michigan Technological University and the International Association of Bryologists

Hayakawa, K. (2018). Polycyclic Aromatic Hydrocarbons || Toxicities of Polycyclic Aromatic Hydrocarbons in Fish and Marine Invertebrates.,*10.1007/978-981-10-6775-4(Chapter 19), 245–259.* doi:10.1007/978-981-10-6775-4_19

Hennings, A. (2021). Nigeria - Context and Land Governance. Retrieved July 24, 2021, from https://landportal.org/book/narratives/2021/nigeria

Hodal, K. (2017). 'Absolute shocking': Niger Delta oil spill linked with infant deaths. Retrieved April 10, 2021, from https://www.theguardian.com/global-development/2017/nov/06/niger-delta-oil-spills-linked-infant-deaths

Huang, X.-D., Dixon, D. G., Greenberg, B. M., Babu, T. S., & Greenberg, B. M. (1997). Mechanisms of photoinduced toxicity of photomodified anthracene to plants: Inhibition of photosynthesis in the aquatic higher plant Lemna gibba (duckweed). *Environmental Toxicology and Chemistry, 16*(8), 1707–1715. https://doi.org/10.1002/etc.5620160819

Huang, X. -D., Dixon, D. G., & Greenberg, B. M. (1993). Impacts of UV radiation and photomodification on the toxicity of pahs to the higher plant Lemna gibba (duckweed). *Environmental Toxicology and Chemistry, 12*(6), 1067–1077. https://doi.org/10.1002/etc.5620120613

Huxham, M., Whitlock, D., Githaiga, M. *et al.* Carbon in the Coastal Seascape: How Interactions Between Mangrove Forests, Seagrass Meadows and Tidal Marshes Influence Carbon Storage (2018). *Curr Forestry Rep*, 4**,** 101–110. https://doi.org/10.1007/s40725-018-0077-4

Ibe, A. C., & Awosika, L. F. (1991). Sea level rise impact on African coastal zones. In S. H. Omide, and C. Juma (Eds), *A change in the weather: African perspectives on climate change*. (pp. 105-112). Nairobi, Kenya: African Centre for Technology Studies.

Ibimilua, A. F. (2013). Biodiversity-ecosystem management and sustainable development in Ekiti State, Nigeria. *British Journal of Humanities and Social Sciences, 9*(1), 35–44

Ifeanyieze, F.O., Alkali, M., Okoye, R. N., & Ikehi, M. E. (2016). Altered climate and livelihood of farming families in Niger Delta region of Nigeria. *African Journal of Agricultural Research*, *11*(10), 882-888. https://doi.org/10.5897/AJAR2015.10716

Igbiri, S., Udowell, N. A., Ekhator, O. C., Asomugha, R. N., Igweze, Z. N., & Orisakwe, O. E. (2017). Polycyclic Aromatic Hydrocarbons in Edible Mushrooms from Niger Delta, Nigeria: Carcinogenic and Non-Carcinogenic Health Risk Assessment. *Asian Pacific Journal of Cancer Prevention*, *18* (2), 437-447. https://doi.org/10.22034/APJCP.2017.18.2.437

Igu, N. (2017). Swamp Forest Use and Loss in the Niger Delta: Contextual and Underlying Issues. *Open Journal of Forestry*, *7*(1), 34-47. http://doi.org/10.4236/ojf.2017.71003

Igu, N. I., & Marchant, R. (2016). Aboveground carbon storage in a freshwater swamp ecosystem in the Niger Delta. *Carbon Management*, *7*(3-4), 137-148

Igu, N. I., & Marchant, R. (2018). Ecological patterns and sustainability of freshwater swamp forest ecosystems: assessing climate and disturbance interactions. *Singapore Journal of Tropical Geography*, *39*(1), pp 62-74

Igu, N, & Marchant, R. (2017). Freshwater swamp forest use in the Niger Delta: perception and insights. *Journal of Forest Research*, *22*(10), 44-52. https://doi.org/10.1080/13416979.2017.1280887

Ihunwo, O., Shahabinia, A. R., Udo, K. S., Bonnail, E., Onyema, O. M., Dibofori- Orji, A. N., Mmon, P. C. (2019). Distribution of polycyclic aromatic hydrocarbons in Woji Creek, in the Niger Delta. *Environmental Research Communications*, *1*(12). https://doi.org/10.1088/2515-7620/ab50f2

Ijekeye, J. (2019). Philosophy and peaceful co-existence among the Niger Delta people and oil companies in Nigeria. *Nnamdi Azikiwe Journal of Philosophy*, *11*(4), 14-35. Retrieved from https://www.nigerianjournalsonline.com/index.php/najp/article/view/533/524

Ikehi, M. E., Onu, F. M., Ifeanyieze, F. O., & Paradang, P. S. (2014). Farming Families and Climate Change Issues in Niger Delta Region of Nigeria: Extent of Impact and Adaptation Strategies. Agricultural Sciences, 5(2), 1140-1151. https://doi.org/10.4236/as.2014.512124

Ikhuoriah, S. O., Oronsaye, C. G., & Adebanjo, I. A. (2015). Zooplankton Communities of the River Ossiomo, Ologbo, Niger Delta, Nigeria. *Animal Research International*, *12*(3), 2249-2259. Retrieved from https://www.ajol.info/index.php/ari/article/view/130572

International Bird Rescue. (n.d.). How oil affects birds. Retrieved July 04, 2021, from https://www.birdrescue.org/our-work/research-and-innovation/how-oil-affects-birds/

IUCN. (n.d.) Mangrove and coastal ecosystems. Retrieved from December 11, 2020, fro, https://www.iucn.org/theme/marine-and-polar/our-work/climate-change-and-ocean/mangroves-and-coastal-ecosystems#:~:text=Mangrove%20forests%20make%20up%20one,species%20living%20between%20tree%20trunks

Iwubeh, J. C., Ikechukwu, I. A., Praise, E. T., Azubuike, A.C., & Francise, A.C. (2020). Effects of crude oil treat-ment on the morphology and performance of water hyacinth (Eichhornia crassipes (Mart) Solms) in Niger-Delta region of Nigeria. *Archives of Agriculture and Environmental Science*, *5*(2), 151-156. https://dx.doi.org/10.26832/24566632.2020.0502010

Izah, S. C., Aigberua, A. O., & Nduka, J. O. (2018). Factors affecting the population trend of biodiversity in the Niger Delta region of Nigeria. *International Journal of Avian and Wildlife Biology*, *3*(3), 199–207. https://doi.org/10.15406/ijawb.2018.03.00085

Izah, S. C. (2018). Ecosystems of the Niger Delta of Nigeria: Potentials and Threats. *Biodiversity International Journal*, *2*(4), 338-345. https://doi.org/10.15406/bij.2018.02.00084

Kadafa, A. A. (2012a). Environmental Impacts of Oil Exploration and Exploitation in the Niger Delta of Nigeria. *Global Journal of Science Frontier Research Environment & Earth Science*, *12*(3), 19-28

Kadafa, A. A. (2012b). Oil Exploration and Spillage in the Niger Delta of Nigeria. *Civil and Engineering Research*, 2, 38 - 51.

King, M. D., Elliott, J. E., & Williams, T. D. (2020). Effects of Petroleum Exposure on Birds: A Review. *Science of The Total Environment, 755,* 142834. *https://doi.org/*doi:10.1016/j.scitotenv.2020.142834

Kougnimon, F. E. E., Akpovi, D. C., Dah-Nouvlessounon, D., Boya, B., Baba, M. L., & Loko F. (2018). Antioxidant and Antibacterial Activities of Terminalia superba Engl. and Diels (Combretaceae) Bark Extracts. *International Journal of Current Microbiology and Applied Science*, *7*(7), https://doi.org/10.20546/ijcmas.2018.707.332

Kuenzer, C., Beijma, S., Gessner, U, & Dech, S. (2014). Land surface dynamics and environmental challenges of the Niger Delta, Africa: Remote sensing-based analysis spanning three decades (1986-2013). *Applied Geology, 53*, 354-368. https://doi.org/10.1016/j.apgeog.2014.07.002

Kumari, P., Singh, J. K., & Pathak, B. (2020). *Potential contribution of multifunctional mangrove resources and its conservation. Biotechnological Utilization of Mangrove Resources, 1–26.* doi:10.1016/b978-0-12-819532-1.00001-9

Kwon, Y., Lemieux, M., McTavish, J.; Wathen, N. (2015). Identifying and removing duplicate records from systematic review searches. J*ournal of the Medical Library Associatio*n, *103*(4), 184–188. https://doi.org/10.3163/1536-5050.103.4.004

Langangen, Ø., Olsen, E., Stige, L. C., Ohlberger, J., Yaragina, N. A., Vikebø, F. B., Bogstad, B. Stenseth, N. C., & Hjermann, D. Ø. (2017). The effects of oil spills on marine fish: Implications of spatial variation in natural mortality. *Marine Pollution Bulletin, 119*(1), 102-209. https://doi.org/10.1016/j.marpolbul.2017.03.037

Lawal, A. T. (2017). Environmental chemistry, pollution and waste management review article. *Cogent Environmental Sciences, 3*, 1-89

Law, J. (2004). Cercopithecus sclateri. *Animal Diversity Web*. Retrieved March 24, 2021, from https://animaldiversity.org/accounts/Cercopithecus_sclateri/

Lindén, O., & Pålsson, J. (2013). Oil contamination in Ogoniland, Niger Delta. *AMBIO, 42*, 685–701. https://doi.org/10.1007/s13280-013-0412-8

Ložek, F., Kuklina, I., Grabicová, K., MilošBuˇriˇc, J. K., Randák, T., Císaˇr, P. & Kozák, P. (2020). Cardiac and locomotor responses to acute stress in signal crayfish *pacifastacus leniusculus* exposed to methamphetamine at an environmentally relevant concentration. *International Journal of Environmental Research and Public Health*, *17*(6), 2084. https://doi.org/10.3390/ijerph17062084

Luiselli, L., Amori, G., Akani, G. C., & Eniang, E. A. (2015). Ecological diversity, community structure and conservation of Niger Delta mammals. *Biodiversity and Conservation, 24*(11), 2809-2830. https://doi.org/10.1007/s10531-015-0975-8

Mace, G. B. (2017). Photoenhanced Toxicity of Petroleum to Aquatic Invertebrates and Fish. *Archives of Environmental Contamination and Toxicology*, *73*, 40-46. https://doi.org/10.1007/s00244-016-0360-y

Mahmoud, Y. (2017). The state of the Niger Delta oil spill. Retrieved August 2, 2021, from https://borgenproject.org/niger-delta-oil-spill/

McConkey, B. J., Duxbury, C. L., Pixon, D. G., & Greenberg, B. M. (2009). Toxicity of a PAH photooxidation product to the bacteria photobacterium phosphoreum and the duckweed Lemma gibba: Effect of phenanthrene and its primary photoproduct, phenanthrenequinone. *Environmental Toxicology and Chemistry, 16*(5), 892 - 899.

Miller, V. (2016). Why we Flare. Retrieved April 28, 2021 from http://large.stanford.edu/courses/2016/ph240/miller1/

Mogaji, O. Y. (2018). The Political Ecology of Oil and Gas Activities in the Nigerian Aquatic Ecosystem. In P. E. Ndimele (Eds.), *The Effects of Crude Oil Exploration on Fish and Fisheries of Nigerian Aquatic Ecosystems*. (pp. 447–467). doi:10.1016/B978-0-12-809399-3.00008-2

Mogaji, O. Y., Sotolu, A. O., Wilfred-Ekprikpo, P. C. & Green, P. M. (2018). The Effects of Crude Oil Exploration on Fish and Fisheries of Nigerian Aquatic Ecosystems. In P. E. Ndimele (Eds), *The Political Ecology of Oil and Gas Activities in the Nigerian Aquatic Ecosystem*. (pp. 125-142). Cambridge: Academic Press

Moomin, Aliu; Mensah, Kwesi Boadu; Forkuo, Arnold Donkor; Adu-Gyamfi, Paa Kofi Tawiah; Ansah, Charles (2020). *Ethanolic stem bark extract of Terminalia ivorensis A. Chev. protects against potassium dichromateâinduced nephrotoxicity in rats. Scientific African, 8(), e00410–.* doi:10.1016/j.sciaf.2020.e00410

Morley, E. L., Jones, G., & Radford, A. N. (2013). The importance of invertebrates when considering the impacts of anthropogenic noise. *Proceedings of the Royal Society B: Biological Sciences, 281*(1776), 20132683–20132683. *https://doi.org/*10.1098/rspb.2013.2683

Moslen, M., Miebakab, C.A., & Boisac, N. (2019). Bioaccumulation of Polycyclic Aromatic Hydrocarbon (PAH) in a bivalve (Arca senilis- blood cockles) and health risk assessment. *Toxicology Reports, 6*(2019), 990–997. https://doi.org/10.1016/j.toxrep.2019.09.006

Murphy, D. (2020). New Community Conservancy Created in Nigeria to Protect Critically Endangered Red Colobus Monkey. Retrieved May 04, 2021, from https://www.rewild.org/press/new-community-conservancy-created-in-nigeria-to-protect-critically-endangered-red-colobus-monkey

Muspratt, A. (2019). The World's Biggest Oil Companies in 2019. Retrieved April 23, 2021, from https://www.oilandgasiq.com/strategy-management-and-information/articles/oil-and-gas-companies#:~:text=There%20are%20over%20200%20oil%20and%20gas%20companies%20in%20the%20world

Nababa, I. I.,Symeonakis, E., Koukoulas, S., Higginbottom, T. P, Cavan, G., & Marsden, S. (2020). Land Cover Dynamics and Mangrove Degradation in the Niger Delta Region. *Remote Sensing, 12*(21), 3619, https://doi.org/10.3390/rs12213619

Nriagu, J. (2011). Oil Industry and the health of communities in the Niger Delta of Nigeria. In Encyclopedia of Environmental Health. *Encyclopedia of Environmental Health*. (pp. 240–250). https://doi.org/10.1016/B978-0-444-52272-6.00736-4

Nriagu, J., Udofia, E. A., Ekong, I. & Ebuk, G. (2016). Health Risks Associated with Oil Pollution in the Niger Delta, Nigeria. International Journal of Environmental Research and Public Health, 13(346), 1-23. https://doi.org/doi:10.3390/ijerph13030346

NSW Government. (2019). Soil degradation. Retrieved June 18, 2021 from https://www.environment.nsw.gov.au/topics/land-and-soil/soil-degradation

Numbere, A. O. (2019). Impact of Invasive Nypa Palm (Nypa Fruticans) on Mangroves in Coastal Areas of the Niger Delta Region, Nigeria: Coasts in Crisis. In C. Makowski, C. W. Finkl (Eds.), *Impacts of Invasive Species on Coastal Environments*, Springer International Publishing AG, part of Springer Nature 2019. https://doi.org/10.1007/978-3-319-91382-7_13

Numbere, A. O. (2021). Impact of Urbanization and Crude Oil Exploration in Niger Delta Mangrove Ecosystem and Its Livelihood Opportunities: A Footprint Perspective. In A. Banerjee et al. (Eds.), *Agroecological Footprints Management for Sustainable Food System*. (pp. 309-344). Singapore: Springer Nature.

Numbere, A. O. (2018). The Impact of Oil and Gas Exploration: Invasive Nypa Palm Species and Urbanization on Mangroves in the Niger River Delta, Nigeria. In C. Makowski, C. W. Finkl (Eds.). *Threats to Mangrove Forests*. (pp. 247-266). Cham: Springer

Nwachukwu, I. & Mbachu, I . C. (2018). The socio-cultural implications of crude oil exploration in Nigeria. In P. E. Ndemele. *The Political Ecology of Oil and Gas Activities in the Nigerian Aquatic Ecosystem*. Pages 447-467, Academic Press - 2018 Elsevier Inc. doi: https://doi.org/10.1016/C2015-0-05649-0

Nwineewii, J. D., & Marcus, A. C. (2015). Polycyclic Aromatic Hydrocarbons (PAHs) In Surface Water and Their Toxicological Effects in Some Creeks of South East Rivers State (Niger Delta) Nigeria. *IOSR Journal of Environmental Science, Toxicology and Food Technology*, *9*(12), 27-30. https://doi.org/10.9790/2402-091222730

Nwozor, A, Audu, J., & Adama, J. I. (2019). The Political Economy of Hydrocarbon Pollution: Assessing Socio-Ecological Sustainability of Nigeria's Niger Delta Region. *International Journal of Energy Economics and Policy*, *9*(1), 1-8. https://doi.org/10.32479/ijeep.7058

Obida, C., Alan, B., Duncan, W. & Semple, K. (2018). Quantifying the exposure of humans and the environment to oil pollution in the Niger Delta using advanced geostatistical techniques. *Environment International*, 111, 32–42. https://doi.org/10.1016/j.envint.2017.11.009

Obida, C., Blackburn, G. A. & Whyatt, D. & Semple, K. T. (2017). Quantifying the exposure of humans and the environment to oil pollution in the Niger Delta using advanced geostatistical techniques. *Environment international*, *111*, 32-42. https://doi.org/10.1016/j.envint.2017.11.009

Ofulu, H. (2017). Negligence of duty by oil companies, regulatory bodies in host communities. Retrieved July 10, 2021, from https://www.vanguardngr.com/2017/12/negligence-duty-oil-companies-regulatory-bodies-host-communities/

Oghenetega, O. B., Ana, G. R., Okunlola, M. A., & Ojengbede, O. A. (2020a). Miscarriage, stillbirth, and infant death in an oil polluted region of the Niger Delta, Nigeria: A retrospective cohort study. *International Journal of Gynecology & Obstetrics*, *150*(3), 361-367. https://doi.org/10.1002/ijgo.13259

Oghenetega,O. B., Ojengbede, O. A., & Ana, G. A. (2020b). Perception Determinants of Women and Healthcare Providers on the Effects of Oil Pollution on Maternal and Newborn Outcomes in the Niger Delta, Nigeria. I*nternational Journal of Women's Health*, *12*, 197-205. https://doi.org/10.2147/IJWH.S235536

Ohanmu, E. O., Igiebor, F. A., Bako, S. P., & Danazumi, I. B. (2018). Impact of Crude Oil on Physicochemical Properties and Trace Metals of Soil before and after Planting of Two Pepper species (*Capsicum annum* L and *C. frutescens* L). *Journal of Applied Sciences and Environmental Management*, *22*(5), 765–768. https://doi.org/10.4314/jasem.v22i5.30

Ohimain, E. I. (2016). Mangroves of the Niger Delta: Their Importance, Threats, and Possible Restoration. Retrieved May 14, 2021, from https://issuu.com/societyofwetlandscientists/docs/dec_2016_wsp/s/132376

Okonokhua, B. O, Ikhajiagbe, B., Anoliefo, G. O., Emede, T. O. (2007). The Effects of Spent Engine Oil on Soil Properties and Growth of Maize (Zea mays L.). *Journal of Applied Sciences and Environmental Management*, *11*(3), 147-152

Okoye, E. A., Bocca, B., Ruggieri, F., Ezejiofor, A. N., Nwaogazie, I. L., Domingo, J. L., Rovira, J., Frazzoli, C., & Orisakwe, O. E. (2021). *Environmental Research*, *198*, 11271. https://doi.org/10.1016/j.envres.2021.111273

Okpara, D. A., & Kharlamova, M. D. (2018). The Anthropogenic Effects of Oil Exploration on Ecological Forest: A Paradox for Agriculture and Environmental Sustainability in Niger Delta Region, Nigeria. *Journal of Agriculture and Environment*, *2*(6), 1-13

Olaji, E. D., Nwogu, N. A., Yakubu, A. F., & Olaji, C. O. (2014). Assessment of Total Hydrocarbon Concentration in Four Fish Species of Degele Community, Nigeria and Their Dietary Intake in the Populace. *Advances in Research*, *2*(2), 109-118

Omamoke, C. O., & Achi, A. H. (2012). The composition and richness of freshwater forest land snail faunas in Okpai, Delta State, *Nigeria. African Scientists*, *13*(3), 119-126.

Omeire, E. U., Aveuya, A. A., Muoneme, O. T., Adolphus, G., Omeire, C. A. & Ufomba, A. (2014). Between the devil and the deep blue sea: Niger Delta women and the burden of gas flaring. *European Scientific Journal*, *10*(26), 151-162. https://doi.org/10.19044/esj.2014.v10n26p%25p

Omokhua, G. E. & Koyejo, A. O. (2008). Impact of Deforestation on Ecosystem: A Case study of the freshwater swamp forest in Onne, Niger Delta Region, Nigeria. Journal of Agriculture and Social Research, *8*(2). https://doi.org/10.4314/jasr.v8i2.43349

Onu, N. C. (2003). The oil rich Niger Delta region: a framework for improved performance of the Nigerian regulatory process. *Ambio: A Journal of the Human Environment*, *32*(4), 325-6.https://dio.org/10.1579/0044-7447-32.4.325

Onyechi, K. C., Eseadi, C., Ugwuozor, F. O., Omeje, J. C. & Ngwoke, D. U. (2016). Probable Psychological Impacts of Environmental Pollution (Oil Spills) in the Coastal Areas of the Niger Delta of Nigeria: a Philosophical Discourse. American-Eurasian J. Agric. & Environ. Sci., 16 (2): 374-379. https://doi.org/10.5829/idosi.aejaes.2016.16.2.10299

Onyemachi, J. (2012). *Oil related environmental degradation and human displacement: case study of Niger Delta Nigeria* [Master's thesis, Mississippi State University]. Theses and Dissertations. https://hdl.handle.net/11668/17944

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, https://doi.org/10.1016/j.gecco.2020.e00961

Onwurah, I. N. E., Ogugua, V. N., Onyike, N. B., Ochonogor, A. E., & Otitoju, O. F. (2007). Crude oil spills in the environment, effects and some innovative clean-up biotechnologies. *International Journal of Environmental Research*, *1*(4), 307-320. https://doi.org/10.22059/IJER.2010.142

Ordinioha, B. & Brisibe, S. (2013). The human health implications of crude oil spills in the Niger delta, Nigeria: An interpretation of published studies. *Journal of the Nigeria Medical Association*, *54*(1), 10-16. https://doi.org/10.4103/0300-1652.108887

Ordinioha, B. & Sawyer, W. (2008). Food Insecurity, Malnutrition and Crude Oil Spillage in a Rural Community in Bayelsa State, South-South Nigeria. *Nigerian Journal of Medicine*, *17*(3), 304-9. https://doi.org/10.4314/njm.v17i3.37400

Oriaku, T. O., Udo, N. A., & Iwuala, I. S. (2017, July 31-August 2). *Assessment of oil spill occurrences in sections of the Niger Delta Region: Causes, Effects and Remedial Actions* [paper presentation]. Nigeria Annual International Conference and Exhibition, Lagos, Nigeria.

Orisakwe, O. E. (2021). Crude oil and public health issues in Niger Delta, Nigeria: Much ado about the inevitable. *Environmental Research*, *194*(2021), 110725. https://doi.org/10.1016/j.envres.2021.110725

Orisakwe, O. E., Njan, A. A., Afonne, O. J., Akumka, D. D., Orish, V. N., & Udemezue, O. O. (2004). Investigation into the Nephrotoxicity of Nigerian Bonny Light Crude Oil in Albino Rats. *International Journal of Environmental Research and Public Health,1*(2), 106-110. https://doi.org/10.3390/ijerph2004020106

Orji, S. (2020). Inside the fight to save the Niger Delta red colobus. Retrieved April 28, 2021, from https://news.mongabay.com/2020/03/inside-the-fight-to-save-the-niger-delta-red-colobus/

Osawaru, M., Ogwu, M. C., & Ahana, C. M. (2013). Current status of plant diversity and conservation in Nigeria. *Nigerian Journal of Life Sciences*, 3, 168-178

Osuagwu, E. S., & Olaifa, E. (2018). Effects of oil spills on fish production in the Niger Delta. *PLoS ONE*, *13*(10): e0205114. https://doi.org/10.1371/journal.pone.0205114

Oteh, C. O., & Eze R. C. (2012). Vandalization of Oil Pipelines in the Niger Delta Region of Nigeria and Poverty: An Overview. Studies in Sociology of Science, 3(2), 13-21. https://doi.org/10.3968/j.sss.1923018420120302.2950

Özen, F., Acemi, A., Pelin, E. G., & Ergül, H. A. (2017). Assessment of Macrophyte Plant Distribution and PAH Contamination in Selected Aquatic Habitats from an Industrialized City; Kocaeli, Turkey. *Biomonitoring, 4*(1), 27-33. https://doi.org/10.1515/bimo-2017-0003

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulro, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A, Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., McGuinness, L. A., Stewart, L. A., Thomas, J., Tricco, A. C., Welch, V. A., Whiting, P., & Moher, D. (2020). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ 2021*, *372*. https://doi.org/10.1136/bmj.n71

Pennings, S. C., McCall, B. D., & Hooper-Biu, L., (2014). Effects of Oil Spills on Terrestrial Arthropods in Coastal Wetlands. BioScience, *64*(9), 789 - 795.

Pickl, M. J. (2019). The renewable energy strategies of oil majors – From oil to energy?. *Energy Strategy Reviews*, *26*, 100370. https://doi.org/doi:10.1016/j.esr.2019.100370

Rafikova, O., Al Ghouleh, I., & Rafikov, R. (2019). Focus on early events: pathogenesis of pulmonary arterial hypertension development. *Antioxidants & Redox Signaling*, *31*(13), 933-953. https://doi.org/10.1089/ars.2018.7673

Ramirez, M. I., Arevalo, A. P., Sotomayor, S., & Bailon-Moscoso, N. (2017). Contamination by oil crude extraction-Refinement and their effects on human health. *Environmental Pollution*, *231*(2017), 415-425. http://dx.doi.org/10.1016/j.envpol.2017.08.017

Ratcliffe, R. (2019). “This place used to be green’: the brutal impact of oil in the Niger Delta. Retrieved July 20, 2021 from https://www.theguardian.com/global-development/2019/dec/06/this-place-used-to-be-green-the-brutal-impact-of-oil-in-the-niger-delta
Rotimi, J., Agwu, E. J., El Bokl, M. M., & Uwagbae, M. A. (2014). Impact of age of crude oil spillage on arthropod diversity at varied soil depths in part of Niger Delta, Nigeria. Nigerian Journal of Life Sciences, 4(1), 2-25. Retrieved from https://www.researchgate.net/profile/Michael-Uwagbae/publication/303263298_Impact_of_age_of_crude_oil_spillage_on_arthropod_diversity_at_varied_soil/links/582ef29308ae004f74be2fff/Impact-of-age-of-crude-oil-spillage-on-arthropod-diversity-at-varied-soil.pdf

Satyakti, Y. (2017). Multinational Oil Companies and Energy Security in the Emerging Economies. Retrieved March 25, 2021 from https://ssrn.com/abstract=3037491

Seiyaboh, E. I., & Izah, S. C. (2017). A Review of Impacts of Gas Flaring on Vegetation and Water Resources in the Niger Delta Region of Nigeria. *International Journal of Economy, Energy and Environment*, *2*(4), 48-55

Shen, G., Zhang, Y., Wei, S., Chen, Y., Yang, C., Lin, P., Xie, H., Xue, M., Wang, X., & Tao, S. (2014). Indoor/outdoor pollution level and personal inhalation exposure of polycyclic aromatic hydrocarbons through biomass fuelled cooking. *Air Quality, Atmosphere & Health*, *7*, 449–458

Shu, E., Otuu, C., Ignatius, M., Abutu, M, Ilouno, L., Obi-Ezeani, N., Inya-Agha, S., Bello, T. and Okechukwu, C. (2019). Alterations in the Air Pollution Tolerance Indices and Foliar Micro-Structures of Five Medicinal Plants: Implications of Oil-Spill Pollution of Agricultural Farmland in Edugberi Community, Rivers State, Nigeria. *Advances in Clinical Toxicology*, *4*(3), 000164. https://doi.org/10.23880/act-16000164

Sojinu. O. S., Wang, Ji. -Z., Sonibare, O. O., & Zeng, E. Y. (2010). Polycyclic aromatic hydrocarbons in sediments and soils from oil exploration areas of the Niger Delta, Nigeria. *Journal of Hazardous Materials*, *174*(1-3), 641–647. https://doi.org/10.1016/j.jhazmat.2009.09.099

SPDC. (n.d). The Shell Petroleum Development Company of Nigeria (SPDC) is the pioneer and leader of the petroleum industry in Nigeria. It has the largest acreage in the country from which it produces some 39 per cent of the nation's oil. Retrieved July 20, 2021, from https://www.shell.com.ng/about-us/what-we-do/spdc.html

Stephansen, D. A., Arias, C. A., Brix, H., Fejerskov, M. L., Nielsen, A. (2020). Relationship between Polycyclic Aromatic Hydrocarbons in Sediments and Invertebrates of Natural and Artificial Stormwater Retention Ponds. *Water, 12*(7). https://doi.org/10.3390/w12072020

Sunderland, T., & Morakinyo, T. (2002). Nypa fruticans, a weed in West Africa. *PALMS*, *46*(3): 154–155

Suzuki, N., Ogiso, S., Yachiguchi, K., Kawabe, K., Makino, F., Toriba, A., Kiyomoto, M., Sekiguchi, T., Tabuchi, Y., Kondo, T., Kitamura, .K, Hong, C. -S., Srivastav, A. K., Oshima, Y., Hattori, A., & Hayakawa, K. (2015). Monohydroxylated polycyclic aromatic hydrocarbons influence spicule formation in the early development of sea urchins (Hemicentrotus pulcherrimus). *Comparative Biochemistry and Physiology Part C: Toxicology & Pharmacology*, *171*, 55–60. https://doi.org/10.1016/j.cbpc.2015.02.004

Thomas, S. C. & Baltzer, J. L. (2002). Tropical forests. *Encyclopedia of life sciences*. London: Macmillan publishers' Ltd, Nature publishing group

Ubogu, M., & Odokuma, L. O. (2019). Growth and tolerance evaluation of selected plants to crude oil contamination in the Niger Delta. *Kuwait Journal of Science*, *46*(4), 93 - 103. Retrieved from https://journalskuwait.org/kjs/index.php/KJS/article/view/4868

Ukpong I. G., & Obok, E. (2018). Implications of crude oil extraction on agriculture and livelihood in oil producing rural communities in Nigeria. *Review of Agricultural and Applied Economics*, *21*(2), 71-77. https://doi.org/10.22004/ag.econ.281199

UNDP. (2006). Niger Delta human development report. Lagos: United Nations Development Program.

U.S. Geological Survey. (2013). Mangrove Changes. Retrieved July 20, 2021, from https://eros.usgs.gov/westafrica/mangrove

Usongo, L. I., & Amubode, F. O. (2001). Nutritional ecology of Preuss's red colobus monkey in Korup National Park, Cameroon. *African Journal of Ecology*, *39*(2), 121–125. https://doi.org/10.1046/j.1365-2028.2000.00279.x

Uwagbae, M. A., Rotimi, J., & Agwu, E. J. (2014). The Pollution of Terrestrial Ecosystem from Hydrocarbon Exploitation and its Outcome on Collembola (Arthropoda: Insecta), Asian Journal of Microbial Biotechnology and Environmental Sciences, *16*(3), 1 -11

Uyigue, E. & Agbo, M. (2007). *Coping with Climate Change and Environmental Degradation in the Niger Delta of Southern Nigeria*. Community Research and Development Centre (CREDC), Benin, Nigeria. CREDC Press, Benin

Watson, C. (2014). Rubber agroforestry in the Niger Delta – hope for youth. Retrieved May 14, 2021, from http://blog.worldagroforestry.org/index.php/2014/07/17/rubber-agroforestry-in-the-niger-delta-hope-for-youth/

Webb, E., Moon, J., Dyrszka, L., Rodriguez, B., Cox, C., Patisaul, H., Bushkin, S., & London, E. (2017). Neurodevelopmental and neurological effects of chemicals associated with unconventional oil and natural gas operations and their potential effects on infants and children. *Reviews on Environmental Health, 0*(0), 1-27. https://doi.org/10.1515/reveh-2017-0008

Winemiller, K. O. (2018). Trends in Biodiversity: Freshwater. In *Encyclopaedia of the Anthropocene* (pp. 151-161). https://doi.org/10.1016/B978-0-12-809665-9.09820-7

World Wildlife Fund (WWF). (2020). Western Africa: Southern Nigeria, extending into Benin. Retrieved December 11, 2020, from https://www.worldwildlife.org/ecoregions/at0123

Yekeen, A. (2019). Future of Nigerian Cocoa production lies in the Niger Delta – Report. Retrieved May 14, 2021, from https://www.icirnigeria.org/future-of-nigerian-cocoa-production-lies-in-niger-delta-report/

Yihui, D., & Sokhi, R. (2008). Global Air Pollution and Climate Change. *World Atlas of Atmospheric Pollution*, 47-65

Zabbey, N., Hart, A. I., & Wolff, W. J. (2010). Population structure, biomass and production of the West African lucinid *Keletistes rhizoecus* (Bivalvia, Mollusca) in Sivibilagbara swamp at Bodo Creek, Niger Delta, Nigeria. Hydrobiologia, 654, 193-203. https://doi.org/10.1007/s10750-010-0381-x

Zhang, B., Matchinski, E. J., Chen, B., Ye, X., Jing, L., & Lee, K. (2019). Marine Oil Spills—Oil Pollution, Sources and Effects. In *World Seas: An Environmental Evaluation.* (pp. 391-406). Cambridge: Academic Press

Appendix: Supplementary Materials

A.1: Thesis Codes with Nodes

Name	Description	Files	References
THE COMPONENTS OF THE ECOSYSTEM IMPACTED BY OIL SPILL, THE EFFECT AND HOW THEY ARE IMPACTED		115	1622
AQUATIC ENVIRONMENT	First Component of the ecosystem impacted	78	344
Aquatic Living Organisms	The impact of oil pollution on Aquatic Environment	62	210
invertebrate	Impacts of oil pollution on Aquatic Living Organisms	35	49
Plants	Impacts of oil pollution on Aquatic Living Organisms	24	38
Vertebrates	Impacts of oil pollution on Aquatic Living Organisms	47	91
Water	The impact of oil pollution on Aquatic Environment	45	96
Water Quality	The impact of oil pollution on water	34	57
HUMANS	Second Component of the ecosystem impacted by oil pollution	88	628
Human health & Mortality Rate	The impact of oil pollution on Human	73	325
Conflicts	Impacts of oil pollution on Human Health and how it increases the Mortality Rate	17	30
Consumption Pattern	Impacts of oil pollution on Human Health and how it increases the Mortality Rate	41	75
Human Exposure	Impacts of oil pollution on Human Health and how it increases the Mortality Rate	22	48

Name	Description	Files	References
Standard of Living	The impact of oil pollution on Human	51	292
Cultural activities	Impacts of oil pollution on Standard of Living	32	75
Source of livelihood & Parental Value	Impacts of oil pollution on Standard of Living	37	145
Human Displacement	Impacts of oil pollution on Standard of Living	16	45
TERRESTRIAL ENVIRONMENT	Third Component of the ecosystem impacted by oil spill	79	645
Agricultural Productivity	Impact of oil pollution on Terrestrial Environment	55	210
Crop Yield	Impacts of oil pollution on Agricultural Productivity	34	79
Food Quality	Impacts of oil pollution on Agricultural Productivity	22	31
Forest Habitat & Ecosystem Services	Impact of oil pollution on Terrestrial Environment	75	422
Vegetation	Impacts of oil pollution on Forest Habitat and Ecosystem Services	45	107
Invertebrate & Microorganism	Impacts of oil pollution on Forest Habitat and Ecosystem Services	24	37
Soil	Impacts of oil pollution on Forest Habitat and Ecosystem Services	63	160
Vertebrates	Impacts of oil pollution on Forest Habitat and Ecosystem Services	28	41

A.2: List of First 200 Words Frequently Used in the articles reviewed

Word Frequency	Length	Count	Weighted Percentage (%)
oil	3	12832	1.08
soil	4	10102	0.85
pollution	9	5087	0.43
delta	5	4556	0.38
water	5	4372	0.37
niger	5	4320	0.36
nigeria	7	3766	0.32
species	7	3115	0.26
land	4	3009	0.25
environment	11	2983	0.25
forest	6	2965	0.25
region	6	2669	0.22
soils	5	2661	0.22
pahs	4	2658	0.22
spill	5	2623	0.22
effects	7	2483	0.21
health	6	2449	0.21
crude	5	2438	0.21
area	4	2181	0.18
metals	6	2069	0.17
food	4	2031	0.17
gas	3	1956	0.16
human	5	1894	0.16
concentrations	14	1876	0.16
areas	5	1863	0.16
natural	7	1819	0.15
exposure	8	1781	0.15
heavy	5	1734	0.15

Sheet1

	A	B	C	D
30	petroleum	9	1699	0.14
31	spills	6	1696	0.14
32	contaminated	12	1690	0.14
33	agricultural	12	1661	0.14
34	activities	10	1655	0.14
35	contamination	13	1648	0.14
36	hydrocarbons	12	1635	0.14
37	ecosystem	9	1609	0.14
38	plant	5	1527	0.13
39	organic	7	1484	0.12
40	aromatic	8	1448	0.12
41	environ	7	1430	0.12
42	concentration	13	1409	0.12
43	well	4	1406	0.12
44	fao	3	1394	0.12
45	people	6	1390	0.12
46	plants	6	1381	0.12
47	river	5	1376	0.12
48	communities	11	1314	0.11
49	pah	3	1276	0.11
50	local	5	1231	0.10
51	polycyclic	10	1231	0.10
52	aquatic	7	1224	0.10
53	mangrove	8	1218	0.10
54	metal	5	1218	0.10
55	resources	9	1218	0.10
56	growth	6	1217	0.10
57	degradation	11	1209	0.10
58	energy	6	1201	0.10
59	toxicity	8	1182	0.10
60	effect	6	1163	0.10
61	economic	8	1144	0.10
62	chemical	8	1118	0.09
63	services	8	1115	0.09
64	marine	6	1101	0.09
65	http	4	1067	0.09
66	many	4	1064	0.09
67	rome	4	1063	0.09
68	higher	6	1042	0.09
69	national	8	1031	0.09
70	freshwater	10	1026	0.09
71	world	5	1026	0.09
72	university	10	1023	0.09
73	www	3	1015	0.09
74	quality	7	1013	0.09
75	symposium	9	997	0.08
76	community	9	994	0.08
77	polluted	8	992	0.08
78	2004	4	982	0.08
79	new	3	971	0.08
80	agriculture	11	970	0.08
81	fish	4	960	0.08
82	theme	5	935	0.08
83	non	3	933	0.08
84	within	6	919	0.08
85	2005	4	918	0.08
86	several	7	884	0.07
87	industrial	10	883	0.07

Sheet1

	A	B	C	D	E
88	biodiversity	12	874	0.07	
89	coastal	7	870	0.07	
90	pollutants	10	864	0.07	
91	exploration	11	861	0.07	
92	government	10	861	0.07	
93	nigerian	8	845	0.07	
94	conditions	10	833	0.07	
95	microbial	9	824	0.07	
96	distribution	12	810	0.07	
97	air	3	808	0.07	
98	sea	3	801	0.07	
99	among	5	777	0.07	
100	forests	7	774	0.07	
101	toxic	5	774	0.07	
102	ecological	10	767	0.06	
103	observed	8	746	0.06	
104	monitoring	10	745	0.06	
105	activity	8	738	0.06	
106	companies	9	731	0.06	
107	treatment	9	727	0.06	
108	organisms	9	717	0.06	
109	properties	10	707	0.06	
110	tree	4	696	0.06	
111	compounds	9	692	0.06	
112	resource	8	691	0.06	
113	africa	6	687	0.06	
114	urban	5	686	0.06	
115	rural	5	685	0.06	
116	ecosystems	10	670	0.06	
117	conservation	12	662	0.06	
118	carbon	6	660	0.06	
119	biological	10	647	0.05	
120	hydrocarbon	11	645	0.05	
121	social	6	638	0.05	
122	industry	8	637	0.05	
123	rivers	6	632	0.05	
124	protection	10	628	0.05	
125	life	4	627	0.05	
126	bacteria	8	625	0.05	
127	elements	8	623	0.05	
128	climate	7	620	0.05	
129	technology	10	614	0.05	
130	benzo	5	611	0.05	
131	diversity	9	607	0.05	
132	pyrene	6	605	0.05	
133	field	5	600	0.05	
134	crops	5	597	0.05	
135	extraction	10	596	0.05	
136	collected	9	586	0.05	
137	lower	5	585	0.05	
138	since	5	575	0.05	
139	less	4	574	0.05	
140	per	3	574	0.05	
141	test	4	574	0.05	
142	com	3	573	0.05	
143	damage	6	572	0.05	
144	shell	5	567	0.05	
145	bioremediation	14	551	0.05	

	A	B	C	D
146	exposed	7	551	0.05
147	group	5	548	0.05
148	livelihood	10	548	0.05
149	vegetation	10	545	0.05
150	safety	6	544	0.05
151	acid	4	543	0.05
152	shown	5	534	0.04
153	pipeline	8	529	0.04
154	flaring	7	528	0.04
155	public	6	528	0.04
156	contaminants	12	520	0.04
157	accumulation	12	517	0.04
158	crop	4	514	0.04
159	temperature	11	512	0.04
160	biodegradation	14	511	0.04
161	farming	7	511	0.04
162	fuel	4	507	0.04
163	households	10	503	0.04
164	possible	8	502	0.04
165	paper	5	498	0.04
166	matter	6	497	0.04
167	techniques	10	497	0.04
168	vol	3	497	0.04
169	although	8	496	0.04
170	res	3	495	0.04
171	amount	6	493	0.04
172	cost	4	489	0.04
173	cancer	6	488	0.04
174	physical	8	488	0.04
175	income	6	487	0.04
176	african	7	463	0.04
177	spillage	8	455	0.04
178	nature	6	450	0.04
179	indigenous	10	442	0.04
180	oils	4	441	0.04
181	cells	5	434	0.04
182	waters	6	432	0.04
183	mangroves	9	413	0.03
184	animals	7	411	0.03
185	lands	5	410	0.03
186	significantly	13	410	0.03
187	trees	5	408	0.03
188	livelihoods	11	397	0.03
189	regional	8	397	0.03
190	drivers	7	396	0.03
191	fish	3	396	0.03
192	density	7	395	0.03
193	palm	4	395	0.03
194	provide	7	395	0.03
195	living	6	394	0.03
196	mortality	9	386	0.03
197	ecology	7	385	0.03
198	sludge	6	385	0.03
199	mining	6	384	0.03
200	birds	5	378	0.03

Sheet1

A.3: Files Used for Data analysis

	A	B
1		Name
2	PDF	4868-Article Text-28596-1-10-20191002
3	PDF	130572-Article Text-352919-1-10-20160216 (1)
4	PDF	A Review of the Effect of Crude Oil Exploration on Agriculture-A Case Study of the-Oil Spill History
5	PDF	A review of the threat of oil exploitation to mangrove ecosystem-Insights from Niger Delta
6	PDF	A review on impact of water pollution on freshwater habitats
7	PDF	AlimbaChukwuka2017
8	PDF	Alterations in the Air Pollution Tolerance Indices and Foliar
9	PDF	Altered climate and livelihood of farming families in
10	PDF	Analysis of Variables of Maritime-induced Oil Spillage in Niger Delta Region of Nigeria (1)
11	PDF	Anthropogenic pollution of aquatic ecosystems
12	PDF	AReviewofImpactsofGasFlaringonVegetationandWater
13	PDF	Assessing the Population Status of the Critically Endangered Niger Delta Red
14	PDF	Assessment of Macrophyte Plant Distribution and
15	PDF	3-s2.0-B9780128093993000082-main (1)
16	PDF	1-s2.0-S0013935121000190-main (1)
17	PDF	Conservation Challenges to Freshwater Ecosystems
18	PDF	Contamination by oil crude extraction e Refinement and their effects
19	PDF	Coping with Climate Change and Environmental Degradation in the Niger Delta of Southern Nigeria
20	PDF	Crude Oil Exploration And Exploitation In Niger-A Christian Concern
21	PDF	Crude Oil Spills in the Environment, Effects and Some Innovative Crude Oil Biotechnology
22	PDF	Chapter13_ImpactsofInvasiveSpp.onCoastalEnvironments
23	PDF	Causes and Terrain of Oil Spillage in Niger Delta Region of Nigeria-The Analysis of Variance Approach
24	PDF	Differences in phytoaccumulation of organic pollutants in freshwater
25	PDF	Distribution of polycyclic aromatic hydrocarbons in
26	PDF	ECOLOGYOFTERRESTRIALHABITAT
27	PDF	Effect of Oil Spillage on Selected Heavy Metals
28	PDF	Effect of Pollution of Freshwater Aquatic Habitats
29	PDF	Effects of Petroleum Exposure on Birds-A Review

Sheet1

	A	B
30	PDF	Effects of pollution on freshwater aquatic organisms
31	PDF	Environmental impacts of oil production in the Niger Delta remote sensing and social survey examination
32	PDF	Environmental pollution and associated health
33	PDF	Evaluation of the Impacts of Oil Spill Disaster on Communities and
34	PDF	Factors_affecting_the_population_trend_of_biodiversity in the Niger Delta Region of Nigeria
35	PDF	Freshwater swamp forest use in the Niger Delta-perception and insights
36	PDF	Gas Flaring in Niger Delta Region of Nigeria_Cost
37	PDF	Health Risks Associated with Oil Pollution in the
38	PDF	Human Health Risk Assessment of Trace Metals in Water from Cross River
39	PDF	IjeomahH.M.AlagoaA.L.andIjeomahA.U.2013
40	PDF	IjeomahH.M.EdetD.I.OruhE.K.andIjeomahA.U.2015 (1)
41	PDF	ILNS.75.1 (1)
42	PDF	Impact of Crude Oil on Physicochemical Properties and Trace Metals of Soil before
43	PDF	Cardiac and Locomotor Responses to Acute Stress in
44	PDF	Impact of Oil Production on Human
45	PDF	Impact of Urbanization and Crude Oil...A footprint perspective
46	PDF	IMPLICATIONS OF CRUDE OIL EXTRACTION ON AGRICULTURE AND LIVELIHOOD IN OIL PRODUCING RURAL COMMUNITIES IN NIGERIA
47	PDF	LEVELS OF POLYCYCLIC AROMATIC HYDROCARBONS IN SOME ORGANS OF TILAPIA SPECIES FROM NEW CALABAR RIVER, NIGER DELTA, NIGERIA
48	PDF	BETWEEN THE DEVIL AND THE DEEP BLUE
49	PDF	Mangrove Habitat Loss and the...
50	PDF	Marine Oil Spill Pollution Causes and Governance-A Case Study of Sanchi Tanker Collision and Explosion
51	PDF	MicrobiologicalqualityofpalmoilusedinNigeria_Healthimpactsperspective (1)
52	PDF	Modelling Crude Oil Spread in Aquatic Environment
53	PDF	A-Survey-on-the-Agricultural
54	PDF	Natural resource extraction and economic and economic performance of Niger Delta Region of Nigeria
55	PDF	NEGLIGENCE IN THE NIGER DELTA REGION
56	PDF	Oil and Gas Pipeline Construction-Induced Forest Fragmentation and Biodiversity Loss in the Niger Delta, Nigeria
57	PDF	Oil and Gas Pipelines versus Environmental Health and Safety in the Niger
58	PDF	Oil exploration and production in Sub-Saharan Africa, 1990-present--Trends

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59	Oil Exploration and Spillage in the Niger Delta of Nigeria
60	Oil Exploration in the Niger Delta-ItsGains and Loss
61	OIL RELATED ENVIRONMENTAL DEGRADATION AND HUMAN
62	Oil Spill Events in Niger Delta Nigeria
63	Oil Spillage and Heavy Metals Toxicity Risk in the Niger
64	Oil Spills-Causes, Consequences, Prevention...
65	OIL, LAND ALIENATION AND IMPOVERIS
66	Oil-Particle Interactions and Submergence from crude oil spills...
67	OVERVIEW OF CRUDE OIL TOXICITY) A POTENTIAL HEALTH
68	PAPER7-Impactofageofcrudeoilspillageonarthropoddiversity
69	PHILOSOPHY AND PEACEFUL CO-EXISTENCE AMONG THE NIGER
70	Photoenhanced Toxicity of Petroleum to Aquatic Invertebrates
71	Physical and Chemical Properties of Crude oil
72	Assessment of Oil Spill Occurrences in the Niger Delta region of Nigeria causes, effects and remediation
73	Deep Ecology Philosophy and Biodiversity
74	Polycyclic Aromatic Hydrocarbons In Edible Mushrooms from
75	Polycyclic Aromatic Hydrocarbons in Sediment and Tissues of the Crab Callinectes
76	Polycyclic aromatic hydrocarbons in sediments and soils from oil exploration
77	Preliminary surveys of the terrestrial vertebrate fauna mammals reptiles and amphibians of the Edumanon Forest Reserve Nigeria
78	Prolonged phenanthrene exposure reduces cardiac function but fails to mount a
79	Quantifying the exposure of humans and the environment to oil pollution
80	Reconnaissance Assessment of Long-Term Effects of Crude Oil Spill
81	Red colombus and their food
82	Reduction in the Biodiversity of the Niger Delta Ecosystem
83	Relationship between Polycyclic Aromatic
84	Some endangered plants producing edible fruits and seeds
85	Impact of Oil Pollution on Livelihood-Evidence from the Niger Delta Region of Nigeria
86	Luisellietal.HerpetolJ14
87	The Effects of Crude Oil Exploration

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88	The effects of oil spills on marine fish- Implications of spatial variation in
89	The Impact of Climate Change on Agro-Ecological Based Livelihoods
90	The Impact of Oil and Gas Exploration-Invasive
91	The Impacts of Petroleum Production
92	The Niger Delta wetlands threats to ecosystem services their importance to dependent communities and possible management measures
93	The renewable energy strategies of oil majors-From oil to energy
94	THE_POLLUTION_OF_A_TERRESTRIAL_ECOSYSTEM
95	TheNigerDeltasvulnerabilitytoriverfloodsduetosealevelrise_NHESS
96	Threat and Conservation of Wildlife Resources in Niger Delta Region of Nigeria
97	TOEBMJ-3-1
98	Toxicities of Polycyclic Aromatic Hydrocarbons for Aquatic Animals
99	TOXICITY OF A PAH PHOTOOXIDATION PRODUCT TO THE BACTERIA
100	Trends in Freshwater Biodiversity
101	Understanding the cardiac toxicity of the anthropogenic pollutant
102	Vandalization of Oil Pipelines in the Niger Delta Region of Nigeria and Poverty An Overview
103	VieetMilieu2015-AkaniTaylorCreek
104	19020-Article Text-35214-2-10-20200326 (1)
105	Effects of crude oil treatment on the morphology and performance of water hyacinth (Eichhornia crassipes (Mart) Solms) in Niger-Delta region of Nigeria
106	Healthimplicationsofcrudeoilspills
107	Investigation into the Nephrotoxicity of Nigerian Bonny Light Crude Oil in Albino Rats (1)
108	j.envpol.2017.08.017
109	Oil-Spills-Injustices-in-the-Niger-Delta-Region (1)
110	MANAGEMENT (FOR BIODIVERSITY) OF FOREST AND OTHER
111	Molluscicidal and Synergicidal Activities of the Leaves of Four Niger Delta Mangrove Plants against Schistosomiasis Vectors
112	cyclic Aromatic Hydrocarbons in Sediment and Tissues of the Crab Callinectes
113	Temporal and spatial variability in macroinvertebrate community structure in relation to environmental variables in Ajijiguan Creek Niger Delta
114	THE ANTHROPOGENIC EFFECTS OF OIL EXPLORATION ON ECOLOGICAL FOREST.A PARADOX FOR AGRICULTURE AND ENVIRONMENTAL SUSTAINABILITY IN NIGER DELTA REGION, NIGERIA
115	Ploycyclic aromatic hydrocarbons (PAHs) & Their Influence to Some Aquatic Species
116	Polycyclic Aromatic Hydrocarbons (PAHs) in inland aquatic

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A.4: The PRISMA Checklist

Section andTopic	Ite m#	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	✓
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	✓
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	✓
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	✓
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	✓
Informationsources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	✓
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	✓
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each recordand each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	✓
Data collectionprocess	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in theprocess.	✓
Data items	10 a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	✓
	10 b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	✓

Study risk of biasassessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	✓
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	✓
Synthesismethods	13 a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics andcomparing against the planned groups for each synthesis (item #5)).	✓
	13 b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or dataconversions.	✓
	13 c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	✓
	13 d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	✓
	13 e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	✓
	13 f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	
Reporting biasassessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	

Section and Topic	Item #	Checklist item	Location where item is reported
RESULTS			
Study selection	16 a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included inthe review, ideally using a flow diagram.	✓
	16 b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	✓

Study characteristics	17	Cite each included study and present its characteristics.	✓
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	✓
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision(e.g. confidence/credible interval), ideally using structured tables or plots.	
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	✓
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	✓
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	✓
	23b	Discuss any limitations of the evidence included in the review.	✓
	23c	Discuss any limitations of the review processes used.	✓
	23d	Discuss implications of the results for practice, policy, and future research.	✓
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	

Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	
Competing interests	26	Declare any competing interests of review authors.	
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from includedstudies; data used for all analyses; analytic code; any other materials used in the review.	