THE MAJOR POLLUTANTS IN MARINE ECOSYSTEM IN DELTA STATE. A CASE STUDY ON THE MARINE LIFE IN DELTA STATE

BY

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CERTIFICATION

We, the undersigned names thereby certify that this research work was carried out by BIOKORO KELVIN OBARO with matriculation Number ENG2006342 AND IYEKE EVANS CHUKWUEMEKA with matriculation Number ENG2006347 in the department of MARINE ENGINEERING, Faculty of ENGINEERING, University of Benin, Benin City, in partial fulfilment of the requirements of the award of (B.Sc.) Degree in MARINE ENGINEERING

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DEDICATION

We, BIOKORO KELVIN OBARO & IYEKE EVANS CHUKWUEMEKA dedicate our project work to Jesus as our Lord and saviour, we also dedicate it to our parents MR & MRS IYEKE AND MR & MRS BENJAMIN for being a system of support and also Miss Olivia for being a backbone of support for the success of this research.

ACKNOWLEDGEMENTS

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Our profound gratitude goes to our wonderful parents, Mr & Mrs. BENJAMIN and HAPPY BIOKORO for their love and support throughout the course of this study and Mr & Mrs. DELE & STELLA IYEKE for their love and support throughout the course of this study, also appreciate my sibling (IYEKE GLORY) for her love and kind gesture. May the Lord bless you abundantly in Jesus Name (AMEN). appreciate Our beloved Family and friends (UNCLE KINGSLEY, TIMOTHY OGBU, FRIDAY OGBU,GIFTY ODU, OSASOGIE HENRY, DONTI BROWN, IGHO LUCKY, CHRISTIAN BIOKORO) AND MY SPIRITUAL HEADS (PASTOR JOHN OLOWO, PASTOR DAVID ATIBIOKE, PASTOR JOSEPH OGBENNIA). For their support and play a vital role to my success. God bless you all. AMEN.

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ABSTRACT

The marine ecosystem in Delta State, Nigeria, plays a crucial role in supporting biodiversity, fisheries, and the livelihoods of coastal communities. However, this ecosystem is increasingly threatened by pollution from various human activities. This study explores the major pollutants affecting the marine environment in Delta State, aiming to identify their sources, types, and impacts.

This study will adopt a single method approach. This design is chosen because it allows for a comprehensive understanding of the problem by quantitative data on the physical presence of pollutants. Quantitative Component That involves the systematic collection and statistical analysis of water and sediment samples to quantify the concentration of specific pollutants. Measurement of pollutant levels in water and sediment samples.

Key pollutants identified include crude oil and petroleum products, heavy metals such as lead and mercury, plastic waste, agricultural runoff containing fertilizers and pesticides, and untreated sewage. These pollutants originate mainly from oil exploration, industrial discharge, poor waste disposal practices, and agricultural activities.The research highlights how these pollutants harm aquatic life, reduce water quality, and disrupt the ecological balance. Fish kills, habitat destruction, and the accumulation of toxins in marine organisms are among the observed effects. The study also considers the social and economic consequences for communities that rely on fishing and marine resources. To address these challenges, the study recommends stronger environmental regulations, improved waste management systems, and community involvement in conservation efforts. Protecting the marine ecosystem in Delta State is essential for sustainable development and the well-being of future generations.

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LIST OF ABBREVIATION

1. NDES: Notice of Discovery of Environmental Significance (Nigerian environmental regulation)

2. UNSD: United Nations Statistics Division

3. DPR: Department of petroleum resources

4. SPDC: Shell Petroleum Development Company (Nigerian oil and gas company)

5. NORM: Naturally occurring radioactive materials

6. NOSDRA: National oil spill detection

7. CMADI: Coastal and marine area development initiative

8. NGOs: Non-Governmental Organizations

9. PAHs: Polycyclic aromatic hydrocarbons

10. DDE: Dichlorodiphenyldichloroethylene (environmental pollutant)

11. DDD: Dichlorodiphenyldichloroethane (insecticide)

12. DDT: Dichlorodiphenyltrichloroethane (insecticide)

13. PCBs: Polychlorinated Biphenyls (toxic chemicals)

14. PH: Measure of water acidity/basicity (potential Hydrogen)

15. NOx: Nitrogen Oxides

16. VOCs: Volatile organic compounds

17. BTEX: Benzene toluene xylenes

18. CD: Cadmium

19. As: Arsenic

20. Cr: Chromium

21. N: Nitrogen

22. P: Phosphorus

23. IPM: Integrated pest management

24. MARPOL: International Convention for the Prevention of Pollution from Ships

25. DDO: Depletion of dissolved oxygen

26. DO: Dissolved oxygen

27. EIA: The environmental impact assessment

28. PIA: The petroleum industry act

29. NUPRC: Nigeria upstream petroleum regulatory commission

30. NESREA: National Environmental Standards and Regulations Enforcement Agency (Nigeria)

31. Ni: Nickel

32. TDS: Total dissolved solid

33. EC: Electrical conductivity

34. COD: Chemical oxygen demand

35. TOC: Total organic compound

36. TPH: Total petroleum hydrocarbon

37. MPs: Member of Parliament or Marine Protected areas, depending on context.

CHAPTER ONE

INTRODUCTION

Marine pollution is man-made marvel that has radical impact on worldwide coastal ecosystem, marine faculty and aquatic assets. It was man-made presentation of materials or energy into the marine surroundings (counting estuaries) straightforwardly or by implication. The marine pollutants has genuine unsafe impact to living assets, risk to human wellbeing, obstacle to marine exercises, including fishing, hindrance of value for utilization of sea-water and decrease of conveniences. Marine pollution is classed as point source or non-point source. Point source pollution happens when there is a solitary, recognizable, and limited wellspring of the pollution. The point wellspring of marine pollution signifies any noticeable, bound and discrete movement wellspring of the pollution and not restricted to any line, discard, channel, burrow, conductor, all things considered, discrete gap, holder, moving stock, concentrated creature taking care of activity, or vessel or other coasting make, from which pollutants are or might be dis-charged. For example, point wellspring of contamination includes straightforwardly releasing sewage (for example water-conveyed waste, in arrangement or suspension, which is proposed to be taken out from a local area, otherwise called wastewater) and modern waste inside the ocean (Mitchell and Diane, 2011). Non-point source pollution involved the pollution that comes from badly characterized and diffuse sources. It comes an as consequence of general gathering of human exercises for which the pollutants have no undeniable mark of section into getting watercourses. Clearly, non-point source pollution could be substantially harder to quantify, recognize and control as to contrast and point sources. The case of non-point source pollution may incorporate horticultural tempest water releases and return streams from flooded farming, metropolitan runoff (from rooftops, roads, parking areas, etcetera), transportation (streets, rail routes, pipelines, hydro-electric passageways) etcetera Ventures and organizations may release wastes to road canals and tempest channels. Over-burdening and breakdown of septic frameworks lead to surface runoff (International Joint Commission the United States and Canada, 1973). Irrefutably, marine pollutions are making decimating and damaging impacts aquatic assets, marine faculty and for the most part the whole marine ecosystem (Sindermann, 2005). It is regularly recognized that human feature assumes a significant part in the contamination of the marine and its surroundings. The mainstream of the destructive substances, for example, poisonous flood and synthetics that causes marine pollution are opened to the seas and oceans by various job players especially the business and shipping organizations (Islam & Tanaka, 2004; Grant & Ross, 2002). Regularly, the wellspring of these piles of garbage and harmful synthetic substances are normally from various human exercises occurred every day like oil slicks, spillages, dumping, and mining (Grant &

Ross, 2002). These exercises are destructive in light of the fact that marine life expressions dangers from various perspectives in the oceans like overexploitation, reaping, store of waste, defilement, extraordinary species, soil recuperation, digging and worldwide environmental change (Vikas & Dwarakish, 2015). This demonstration of marine contamination endures with opportunity until the public authority and the administrative specialists faced it by form laws that wipe out marine pollution.

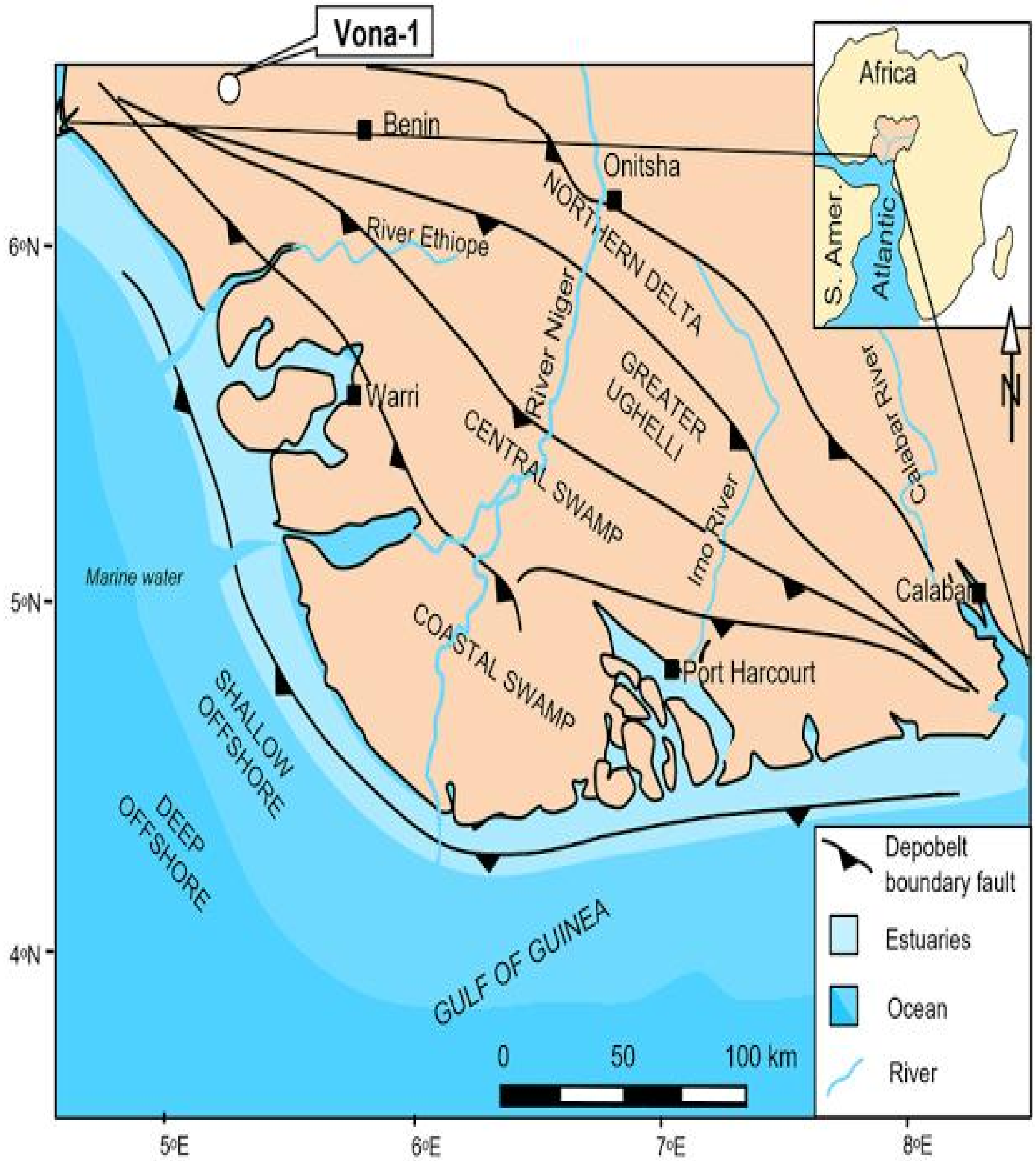
1.1 BACKGROUND OF THE STUDY.

MARINE ECOSYSTEMS

Marine ecosystems are the largest of Earth's aquatic ecosystems and exist in waters that have a high salt content. These systems contrast with freshwater ecosystems, which have a lower salt content. Marine waters cover more than 70% of the surface of the Earth and account for more than 97% of Earth's water supply and 90% of habitable space on Earth. Seawater has an average salinity of 35 parts per thousand of water. Actual salinity varies among different marine ecosystems.

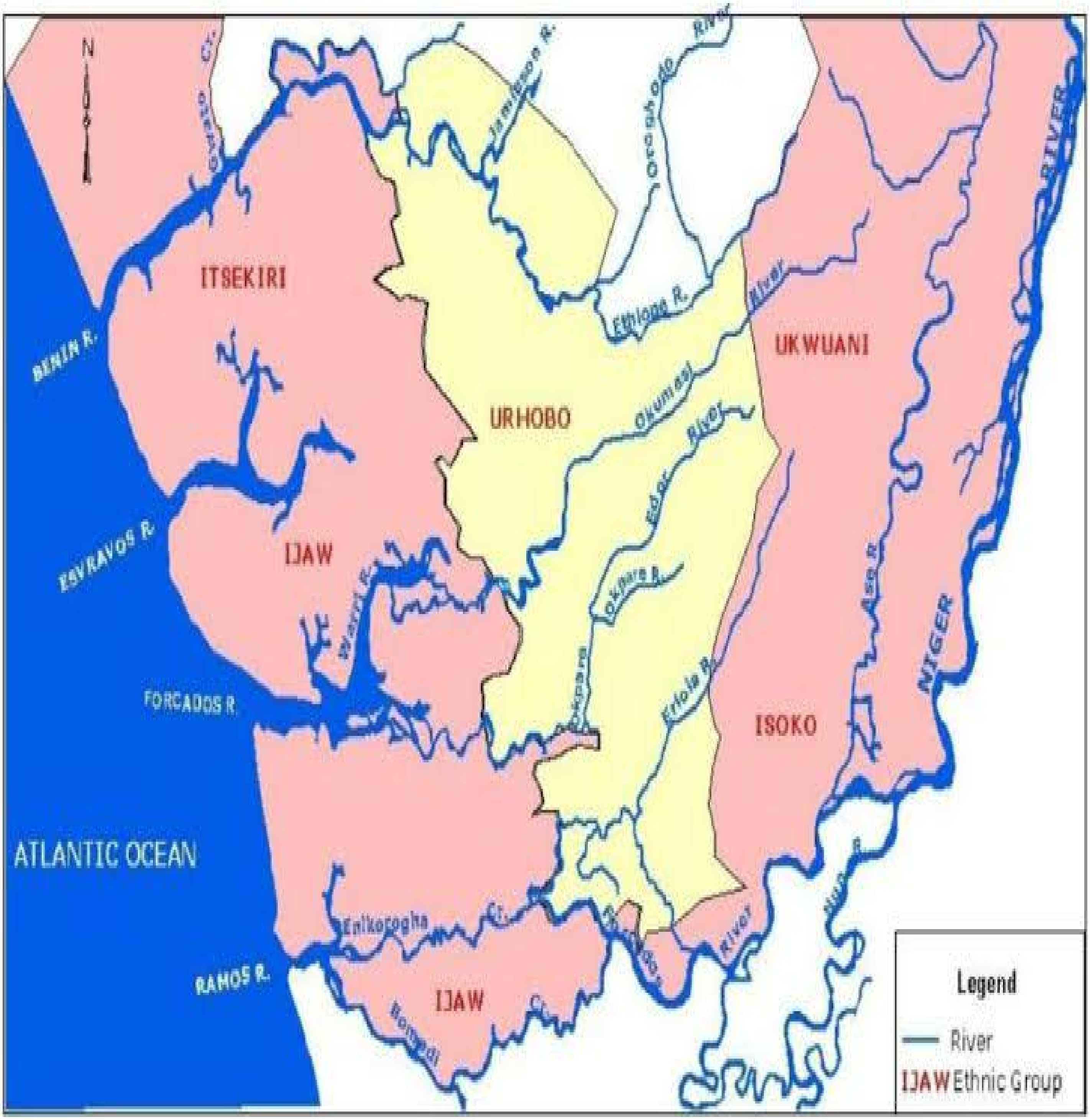
HISTORY OF POLLUTION

The Niger Delta as historically defined comprises the present Delta, Bayelsa and Rivers States in south-south Nigeria (Dike 1956; Willinks et al., 1958; Akinyele 1998). The total area is 25,640 km2; Low Land Area 7,400km2, Fresh Water Swamp 11,700 km2, Salt Water Swamp 5,400 km2 and Sand Barrier Islands 1,140 km2 (Ashton-Jones. 1998). The Niger Delta mangrove ecosystem is the largest in Africa and second largest in the world (Awosika, 1995). It is one of the world’s most fragile ecosystems (NDES, 1997) and the area with the highest fresh water fish species in West Africa (Ogbe 2005). Oil activities started in the Niger Delta in 1908. However, commercial oil production began at Oloibiri, Bayelsa State in 1956 but oil exportation started in 1958. Presently, oil accounts for over 80% of state revenues, 90% of foreign exchange earnings and 96% of export revenues (Ohiorhenan 1984; Ikelegbe 2005; UNSD, 2009). About 2.45 million barrels is produced daily that earns the country an estimated $60 billion annually (Ploch, 2011). Over 85% of oil is produced in the Niger Delta (SPDC, 2008) mostly from the mangrove ecosystem. However, oil activities impact adversely on the marine environment (Lee and Page, 1997; Snape et al., 2001; Liu and Wirtz, 2005), with allied severe socioeconomic effects (Ibeanu, 1997; Roberts, 1999, 2005; Omoweh, 2005). In the Niger Delta, this has been exacerbated by the oil companies’ impunity of operations with no regard for the environment. As, such, oil operation have entailed recurrent oil spillages and massive gas flaring. The impunity of oil operations in the Niger Delta is exemplified by the fact that Shell operations in Nigeria that accounts for just 14% of its oil production worldwide, accounts for a staggering 40% of its oil spills worldwide (Gilbert, 2010). Oil spills records obtained from the Department of Petroleum Resources (DPR) showed that between 1976 and 2005, 3,121.909.80 barrels of oil was spilled into the Niger Delta environment in about 9,107 incidents. Independent researchers have however argued that the volume and incidents of oil spills are under reported (Green Peace, 1994; Banfield, 1998; Iyayi, 2004). Three main mangrove species exists in Nigeria; R. Racemosa, R. mangle and Rhizophora harrisonni (Adegbehin, 1993). Two others of less abundance, Avincennia germinans and Laguncularia racemosa are also present. The mangrove is a highly productive biotope with a vigorous, rich and endemic wildlife, supporting a wide and varied group of mobile organisms ranging from birds that nest in the trees to fishes that feed and live among submerged prop roots (Odum et al., 1982). Mangroves are the most sensitive of all coastal ecosystems (Hayes and Gundlach, 1979). Hydrocarbons are major threat to mangroves (Hanley, 1992; Kadam, 1992; Tarn and Wong, 1995), as high proportions of heavy metals are retained in mangroves sediment (Tarn and Wong, 1995). The mangrove forests and creeks constitute the main areas of oil exploration and exploitation activities in the Niger Delta.



Vona-1
Benin
Onitsha
River Ethiope
NORTHERN DELTA
River Niger
GREATER UGHELLI
Warri
CENTRAL SWAMP
Imo River
Calabar River
Calabar
Port Harcourt
COASTAL SWAMP
Marine water
SHALLOW OFFSHORE
DEEP OFFSHORE
GULF OF GUINEA
Africa
S. Amer.
Atlantic
N
6°N
5°N
4°N
5°E
6°E
7°E
8°E
0
50
100 km
Depobelt boundary fault
Estuaries
Ocean
River

Fig 1



THE MAP OF DELTA STATE

Fig 2

1.2 STATEMENT OF THE PROBLEM.

NEGATIVE ENVIRONMENTAL AND SOCIOECONOMIC IMPACTS OF POLLUTION IN DELTA STATE.

Marine pollution in Delta state has devastating environmental and socioeconomic impacts

ENVIRONMENTAL IMPACTS

- **Ecosystem degradation:** Oil spills destroy vital ecosystems like mangrove swamps, which are critical habitats for marine life.
- **Biodiversity loss:** Pollution leads to a significant decline in species like fish, shrimp, and crabs, and contaminates food sources, impacting the health of the entire marine food web.
- **Water and Soil contamination:** Oil spills, industrial chemicals, and untreated sewage contaminate both rivers and coastal waters, and the resulting soil infertility makes land unusable for agriculture.
- **Habitat destruction:** Oil pollution can increase soil acidity, and plastic debris can physically damage habitats and block waterways.

SOCIOECONOMIC IMPACTS:

- **Livelihood destruction:** The primary economic activities in the region, fishing and farming, are severely undermined by pollution, leading to a drastic decrease in income for many communities.
- **Health problems:** Direct exposure to spilled oil can lead to a range of illnesses, including diarrhea, skin issues, and eye infections. Long-term exposure to pollutants is linked to more severe health risks like infertility and potential cancer.
- **Economic decline:** The cumulative effect of damaged ecosystems and ruined livelihoods results in a significant reduction in overall economic productivity for the stat
- **Disruption of services:** Pollution can make water unsafe for drinking and impact recreational activities, affecting the quality of life for residents.
- **Conflict and crime:** The environmental and economic devastation from pollution has been linked to the rise in maritime crime and community-driven protest tactics, such as pipeline vandalism, as communities react to the destruction of their environment and livelihoods.

1.3 OBJECTIVES OF THE STUDY.

AIM AND OBJECTIVE OF THE STUDY

AIM: TO EXAMINE THE MAJOR POLLUTANTS AFFECTING THE MARINE ECOSYSTEM IN DELTA STATE AND ASSESS THEIR SOURCES, EFFECTS, AND GENERATE POSSIBLE CONTROL MEASURES.

OBJECTIVE:

1. TO IDENTIFY THE MAJOR POLLUTANTS PRESENT IN THE MARINE ECOSYSTEM OF DELTA STATE.

2. TO DETERMINE THE MAJOR SOURCES AND CAUSES OF THESE POLLUTANTS.

3. TO PROPOSE SUSTAINABLE STRATEGIES FOR REDUCING AND MANAGING POLLUTION IN THE MARINE ENVIRONMENT.

1.4 SIGNIFICANCE OF THE STUDY: EXPLAINING THE PROJECT'S RELEVANCE TO LOCAL COMMUNITIES, GOVERNMENT BODIES, ENVIRONMENTAL ORGANIZATIONS, AND ACADEMIC RESEARCHERS.

Local communities:

1. Health: Communities face a high incidence of waterborne diseases (like cholera and typhoid) and other health issues such as respiratory illnesses, skin diseases, and cancer due to contact with contaminated water and exposure to toxic chemicals.
2. Livelihoods: Fishing and farming, the traditional sources of income for many, have been crippled by pollution. Oil spills have destroyed fisheries, killed aquatic life and rendered farmland infertile.
3. Food security: The depletion of fish stocks and degradation of agricultural land leads to food insecurity and increased economic hardship for families.

Government bodies:

1. Enforcement and regulation: Agencies like the National Oil Spill Detection and Response Agency (NOSDRA) are tasked with mitigating spills and enforcing environmental standards,

but their effectiveness is undermined by weak implementation, lack of political will and institutional overlaps.

2. Economic costs: The government bears the economic burden of coastal degradation, including the costs of environmental remediation, disaster response, and supporting affected communities.
3. Public health management: Government health services are strained by the increased burden of waterborne and pollution-related diseases in affected communities.

Environmental organizations:

1. Advocacy and awareness: Organizations like the Coastal and Marine Areas Development Initiative (CMADI) raise awareness about the scale of the pollution and advocate for stronger corporate accountability and government action.
2. Conservation and restoration: NGOs are often involved in mangrove reforestation and biodiversity conservation projects to help restore degraded ecosystems.
3. Community empowerment: They work directly with local communities to develop sustainable livelihoods and educate them on the risks of pollution and measures for mitigation.

Academic researchers:

1. Data collection and analysis: Researchers conduct studies on the concentration of heavy metals, hydrocarbons, and microplastics in water, sediment, and marine organisms. This provides crucial, scientifically-backed evidence of pollution levels.
2. Health impact studies: Medical and social science researchers investigate the link between environmental pollution and the health issues, social disruptions, and economic losses experienced by local communities.
3. Policy development: Academic findings inform policy recommendations and provide the scientific basis for advocacy by NGOs and lobbying for change by affected communities.

1.5 SCOPE OF THE STUDY: DEFINE THE GEOGRAPHICAL AREA (DELTA STATE MARINE AND COASTAL ENVIRONMENTS) AND THE SPECIFIC TYPES OF POLLUTANTS TO BE COVERED.

The geographical area of Delta State's marine and coastal environments includes the estuaries, creeks, mangrove swamps, and nearshore waters where the Forcados and other rivers empty into the Atlantic

Ocean. This low-lying, complex ecosystem is part of the larger Niger Delta, Africa's most extensive wetland and a globally significant biodiversity hotspot.

The main components of the area include:

- Coastal barrier islands and beaches: A series of barrier island ridges running parallel to the Atlantic coastline.
- Mangrove swamp forests: Extensive brackish water areas are subject to tidal changes.
- Freshwater swamps: Ecosystems further inland with low or no salt content.
- Nearshore marine environment: The Atlantic Ocean waters extending seaward from the coast.

TYPES OF POLLUTANTS

1. Oil spills: Releases of crude oil from aging and poorly maintained pipelines, operational failures, and sabotage. This oil contains toxic hydrocarbons and carcinogens like polycyclic aromatic hydrocarbons (PAHs).
2. Gas flaring: The burning of natural gas during oil extraction. This releases significant amounts of methane, carbon dioxide, and other toxic chemicals, including sulfur dioxide, nitrogen oxides, and benzene into the atmosphere.
3. Illegal refining ("Bunkering"): The unauthorized tapping and refining of crude oil releases large quantities of unrefined petroleum products directly into the water and land.
4. Waste discharge: Industrial wastewater and drilling mud are improperly disposed of during oil production.

1.6 LIMITATION OF THE STUDY

General Limitations for Studies on Major Pollutants in Delta State.

Research on environmental pollution in Delta State, while critical, is often conducted within a framework of significant constraints. The limitations of this study—namely, restricted data access, limited funding, and a focused geographical scope—reflect challenges that are endemic to the region.

The following general limitations provide context for these specific constraints.

1. Data Availability and Quality Limitations (This generalizes "Limited Access to Data")

- Sparse and Inconsistent Monitoring Networks: Government-led environmental monitoring in Delta State can be intermittent and geographically limited, often concentrated near major oil and gas facilities while neglecting rural and estuarine communities. This creates significant spatial and temporal data gaps, making it difficult to establish long-term trends or identify diffuse pollution sources.
- Reliance on Self-Reported Data: A substantial amount of environmental data, especially regarding oil spills and gas flaring, originates from the companies responsible. The lack of independent, real-time monitoring can lead to disputes over the volume, cause, and impact of pollution events, introducing potential bias and uncertainty into the data.
- Inconsistent Methodologies: Data collected by different entities (government agencies, NGOs, academic researchers, and corporations) often use different protocols, detection limits, and reporting standards. This lack of harmonization complicates the task of building a comprehensive and comparable dataset for the entire state.

2. Methodological and Analytical Constraints (This generalizes "Limited Funding")
   - Financial and Logistical Barriers: Conducting field research in the Niger Delta is logistically challenging and expensive. Limited funding often restricts the:
   - Scope and Scale: Number of sampling sites and the frequency of sampling campaigns.
   - Analytical Techniques: Ability to use advanced, more accurate (and often more costly) laboratory analyses for complex pollutants like Polycyclic Aromatic Hydrocarbons (PAHs) or heavy metal speciation.
   - Safety and Access: Capacity to safely access remote, volatile, or heavily contaminated sites, which may require specialized equipment and security.
   - Modeling Uncertainties: Computational models used to predict pollutant dispersion (e.g., from gas flares or oil spills) are highly sensitive to input data. In a complex environment like the Niger Delta with its intricate network of creeks, mangroves, and variable weather patterns, the lack of high-resolution, localized data can lead to significant uncertainties in model outputs.

3. Challenges to Generalizability and Scope (This generalizes "Limited Specific Research Locations")

• Spatial Generalizability: Delta State's environment is highly heterogeneous, encompassing urban areas (e.g., Warri), rural agricultural lands, and fragile mangrove ecosystems. Findings from a study focused on one specific location (e.g., a single community near a flow station) may not be directly applicable to other parts of the state with different ecological, industrial, or demographic characteristics.

- Temporal Dynamics: Pollution in Delta State is often episodic (e.g., sudden oil spills) as well as chronic (e.g., continuous gas flaring). A "snapshot" study conducted over a short period may capture the impact of an acute event but miss the long-term, cumulative effects of chronic exposure, or vice versa.

- Complexity of Pollutant Mixtures: The environment in Delta State is typically contaminated by a complex "cocktail" of pollutants from various sources—crude oil, refined products, heavy metals from industrial waste, and agricultural runoff. It is methodologically difficult and prohibitively expensive to isolate the effect of a single pollutant from this mixture, making causal attribution challenging.

1.7 DEFINITION OF TERMS: DEFINE KEY WORS "MARINE ECOSYSTEM," "POLLUTANTS," AND "HEAVY METALS" IN THE CONTEXT OF THE STUDY.

MARINE ECOSYSTEM

Marine ecosystems are the largest of Earth's aquatic ecosystems and exist in waters that have a high salt content. These systems contrast with freshwater ecosystems, which have a lower salt content. Marine waters cover more than 70% of the surface of the Earth and account for more than 97% of Earth's water supply and 90% of habitable space on Earth. Seawater has an average salinity of 35 parts per thousand of water. Actual salinity varies among different marine ecosystems. Marine ecosystems can be divided into many zones depending upon water depth and shoreline features. The oceanic zone is the vast open part of the ocean where animals such as whales, sharks, and tuna live. The benthic zone consists of substrates below water where many invertebrates live. The intertidal zone is the area between high and low tides. Other near-shore (neritic) zones can include mudflats, seagrass meadows, mangroves, rocky intertidal systems, salt marshes, coral reefs, kelp forests and lagoons. In the deep water, hydrothermal vents may occur where chemosynthetic sulfur bacteria form the base of the food web.

POLLUTANTS

It is a substance that pollutes something, especially water or the atmosphere. Marine pollutants are substances that enter oceans and seas, disrupting ecosystems and harming marine life, with major sources including oil spills, plastic waste, chemicals, and agricultural runoff.

A pollutant is a substance or energy introduced into the environment that has undesired effect, or adversely affects the usefulness of a resource. These can be both naturally forming (i.e. minerals or extracted compounds like oil or anthropogenic in origin (i.e. manufactured materials or byproducts). Pollutants result in environmental pollution or become of public health concern when they reach a concentration high enough to have significant negative impacts.

A pollutant may cause long- or short-term damage by changing the growth rate of plant or animal species, or by interfering with resources used by humans, human health or wellbeing, or property values. Some pollutants are biodegradable and therefore will not persist in the environment in a long term. However, the degradation products of some pollutants are themselves pollutants such as DDE and DDD produced from the degradation of DDT.

Pollution has widespread negative impact on the environment. When analyzed from a planetary-boundaries perspective, human society has released novel entities that well exceed safe levels.

HEAVY METALS

Heavy metal is a broad term that describes a group of naturally occurring metallic elements of high molecular weight and density compared to water. Heavy metals is a controversial and ambiguous term for metallic elements with relatively high densities, atomic weights, or atomic numbers. The criteria used, and whether metalloids are included, vary depending on the author and context, and arguably, the term "heavy metal" should be avoided. A heavy metal may be defined on the basis of density, atomic number, or chemical behaviour. More specific definitions have been published, none of which has been widely accepted.

CHAPTER TWO

LITERATURE REVIEW

2.1 Concept on Marine Pollution.

General overview of marine pollution

Marine pollution is defined as the direct or indirect introduction of substances or energy by humans into the ocean, resulting in harm to living resources, human health, and marine activities. While natural factors can contribute to water contamination, marine pollution is fundamentally an anthropogenic problem, with approximately 80% of waste entering the ocean originating from land-based activities.

Sources of marine pollution include:

1. Land-based runoff: Discharge from agriculture, industry, and urban areas transports fertilizers, pesticides, heavy metals, and sewage into waterways that empty into the ocean.
2. Marine-based activities: Operational discharges from ships (e.g., oil, sewage, garbage), intentional dumping, oil spills, and emissions from maritime traffic contribute significant pollutants.
3. Atmospheric deposition: Air pollution from industrial and vehicular emissions can deposit toxic chemicals and particulate matter directly into the ocean.
4. Coastal development: Construction and other coastal activities can cause erosion and disrupt seabed areas, releasing sediment and other contaminants.

TYPES OF MARINE POLLUTION:

Marine pollution can be broadly categorized into three main types based on the nature of the introduced contaminants: chemical, physical, and biological.

CHEMICAL POLLUTION

This category involves the introduction of harmful chemical substances into the marine environment.

1. Nutrient pollution: Excess nitrogen and phosphorus from agricultural fertilizers and untreated sewage cause eutrophication, or over-enrichment of the water. This leads to dense algal blooms that deplete dissolved oxygen, creating hypoxic "dead zones" that kill marine life.
2. Toxic chemicals: Industrial waste and agricultural runoff introduce heavy metals (e.g., mercury, cadmium), pesticides, and industrial chemicals (e.g., PCBs) into the food web. These toxins can

bioaccumulate, reaching high concentrations in top predators and causing health issues like reproductive failure and disease.

3. Oil pollution: Oil spills from tankers, offshore drilling, and runoff introduce hydrocarbons into the ocean, which can be acutely toxic to marine life, disrupt habitats, and harm seabirds.
4. Ocean acidification: The ocean absorbs atmospheric carbon dioxide (CO_2), leading to a decrease in its pH. This chemical change harms calcifying organisms like corals and shellfish and can increase the toxicity of some pollutants.

PHYSICAL POLLUTION

This type of pollution involves the introduction of solid waste, energy, or other physical disturbances.

1. Plastic pollution: One of the most prevalent forms of marine pollution, plastic waste ranges from large debris to invisible microplastics. It harms wildlife through entanglement and ingestion and breaks down into toxic particles that can enter the food web.
2. Marine debris: In addition to plastic, this includes other human rubbish like discarded fishing gear, packaging, and other materials that float on or are suspended in the ocean.
3. Noise pollution: Created by ships, sonar, and oil exploration, underwater noise disrupts the communication, feeding, migration, and reproduction of marine mammals.
4. Thermal pollution: The discharge of heated water from industrial plants, such as power stations, raises the temperature of the surrounding marine environment. This decreases dissolved oxygen levels, stressing aquatic life and altering local ecosystems.
5. Sediment pollution: Land erosion from construction and coastal activities introduces sediment that can smother coral reefs, block sunlight, and physically stress marine organisms.
6. Light pollution: Artificial light from coastal development and offshore platforms can disrupt the natural behaviors of marine life, such as migration and reproduction.

BIOLOGICAL POLLUTION

This occurs when living organisms are introduced to new environments, with harmful effect

1. Pathogens: The discharge of untreated sewage introduces pathogens like bacteria and viruses into coastal waters, contaminating shellfish and causing waterborne diseases in humans, such as cholera and typhoid.

2. Invasive species: Introduced through ballast water from ships, non-indigenous organisms can outcompete native species, disrupt ecosystems, and cause significant economic damage.

GLOBAL IMPACTS OF MARINE POLLUTION

The consequences of marine pollution are far-reaching and affect all aspects of the global ecosystem and human society.

Environmental impacts

1. Loss of biodiversity: Pollution kills and injures a wide variety of marine life n , from microorganisms to mammals, leading to decreased species abundance and ecosystem function.
2. Ecosystem degradation: Critical habitats like coral reefs and seagrass beds are destroyed by contaminants such as sediment, nutrients, and toxic chemicals, which harms the species that depend on them.
3. Disrupted food webs: The accumulation of toxins in marine food chains threatens the health of marine organisms at every trophic level. This process, known as bioaccumulation, can lead to severe health problems and death, and also affects species that depend on marine animals for food.
4. Oxygen depletion: Nutrient pollution and other waste can lead to the formation of "dead zones" where depleted oxygen levels cannot support marine life, forcing organisms to flee or perish.
5. Reduced oxygen production: Harm to microorganisms vital for photosynthesis reduces the ocean's ability to produce oxygen, which poses a serious long-term threat to the planet's atmosphere.

Human health impacts

1. Food contamination: Harmful substances from pollutants can enter the seafood supply. For example, mercury has been found in long-lived fish like tuna and swordfish, posing a risk to human health, especially for developing brains in children and fetuses.
2. Waterborne disease: Pathogens from sewage can contaminate recreational waters and seafood, causing illnesses like diarrhea, skin infections, and viral diseases in humans.

Economic impacts

1. Financial losses: Pollution causes significant economic damage through lost fisheries, reduced tourism revenue, and increased cleanup costs.
2. Livelihood disruption: Coastal communities dependent on fishing and tourism face devastating impacts from marine pollution, leading to social dislocation and increased poverty.
3. Resource depletion: The continuous degradation of marine ecosystems depletes natural resources and undermines the long-term food security of coastal populations.

2.2 Sources and Causes of Pollution in the Niger Delta:

2.2.1 OIL AND GAS ACTIVITIES.

The Environmental and Social Toll of Oil and Gas Activities

The oil and gas industry is a cornerstone of the global energy supply, but its operations are often accompanied by significant environmental degradation and social costs. Three of the most persistent and damaging issues are pipeline spills, improper waste dumping, and gas flaring. Each has distinct causes but converges in their impact on ecosystems, human health, and climate.

1. Pipeline Spills: The Constant Drip of Contamination

Pipelines are the arteries of the oil and gas industry, but they are vulnerable to failures that result in catastrophic spills. The two primary causes are corrosion and vandalism/theft.

CAUSES:

1. Corrosion:

• What it is: The natural deterioration of pipeline metal due to chemical reactions with the environment (e.g., water, soil, and the transported substances themselves).

• Why it happens: Many pipelines are decades old and have exceeded their designed lifespan. Inadequate maintenance, insufficient inspection, and the use of outdated materials make them susceptible to leaks. Internal corrosion can be accelerated by impurities in the oil or gas, while external corrosion is worsened by corrosive soils and moisture.

2. Vandalism and Theft (often called "Oil Bunkering" or "Pipeline Tampering"):

• What it is: The intentional damaging of pipelines to steal crude oil or refined products. This is a massive problem in regions like the Niger Delta in Nigeria.

• Why it happens: Driven by poverty, organized crime, and political grievance, individuals or groups illegally tap pipelines to siphon off oil. This process is often crude and unsafe, leading to major spills and explosions that cause numerous fatalities.

IMPACTS:

• Environmental: Spills contaminate soil, groundwater, and surface water (rivers, lakes, and wetlands). Oil is toxic to plants and wildlife, destroying habitats like mangroves and fish breeding grounds. The long-term contamination can render land infertile for decades.

• Human Health: Communities are exposed to carcinogenic and toxic chemicals like benzene through contaminated drinking water and air pollution. This leads to increased risks of cancer, respiratory problems, and neurological disorders.

• Socio-Economic: Spills destroy the livelihoods of communities dependent on farming and fishing. Contaminated land and water lead to food insecurity and loss of income, fueling a cycle of poverty and conflict.

2. Waste Dumping: The Hidden Legacy of Toxins

Oil and gas extraction generates enormous volumes of waste, much of which is hazardous

Types of Waste:

• Produced Water: The largest volume waste stream. This is water brought up from the hydrocarbon reservoir, which is often highly saline and can contain toxic metals, naturally occurring radioactive materials (NORM), and residual hydrocarbons.

• Drilling Muds and Cuttings: Fluids and rock fragments from the drilling process. These can contain barite, clay, chemicals, and hydrocarbons.

• Other Wastes: Hydraulic fracturing ("fracking") flowback water, contaminated soil, and various industrial wastes.

Causes and Practices:

• Improper Disposal: To cut costs, companies may illegally dump untreated waste into rivers, oceans, or unlined pits instead of treating it or re-injecting it into deep disposal wells.

• Inadequate Regulation: In some regions, environmental laws are weak or poorly enforced, creating a permissive environment for dumping.

IMPACTS:

• Water Pollution: When dumped into surface waters, toxic wastes poisons aquatic life and can enter the human food chain. Leakage from unlined waste pits can contaminate groundwater, which is a primary source of drinking water for many communities.

• Soil Contamination: Renders land unusable for agriculture and poses direct contact risks to humans and animals.

• Radioactive Accumulation: NORM can accumulate in sediments and the food chain, posing long-term radiation risks.

3. Gas Flaring: Burning Money, Warming the Planet

Gas flaring is the controlled burning of natural gas that cannot be processed or captured during oil extraction.

CAUSES:

• Economic and Technical Constraints: The primary reason is the lack of infrastructure (pipelines and processing facilities) to capture, transport, and market the "associated gas" that comes up with oil. It is often cheaper and easier for companies to burn it than to invest in the necessary infrastructure, especially in remote fields.

• Safety: Flaring is sometimes necessary to safely relieve pressure from equipment during emergencies or maintenance.

IMPACTS:

• Climate Change: Gas flaring is a major source of greenhouse gas emissions, releasing millions of tons of CO_2 into the atmosphere annually. It also emits black carbon (soot), a potent short-lived climate pollutant.

• Air Pollution and Health: Flares release a cocktail of harmful pollutants, including sulfur dioxide (SO_2), nitrogen oxides (NOx), and volatile organic compounds (VOCs). For nearby communities, this leads to increased rates of asthma, bronchitis, heart disease, and premature death. The soot can cause and exacerbate respiratory illnesses.

• Economic Waste: Flaring represents a massive waste of a valuable natural resource. The flared gas could be used to generate electricity for millions of homes, fostering economic development

2.2.2 INDUSTRIAL AND DOMESTIC WASTE.

Industrial and Domestic Waste: The Dual Assault on Waterways and Coasts

While oil and gas activities represent a significant point source of pollution, the constant, widespread discharge of industrial and domestic waste creates a pervasive and chronic environmental crisis. This pollution, often flowing directly into rivers, estuaries, and coastal waters, degrades ecosystems, threatens human health, and undermines economic livelihoods on a massive scale.

1. Industrial Effluents: A Cocktail of Toxins

Industrial effluents are liquid waste discharged from manufacturing plants, refineries, mines, and other industrial facilities. They are characterized by their complex and often highly toxic chemical composition.

Key Pollutants and Their Sources

1. Petrochemicals and Organic Chemicals:

- Sources: Oil refineries, plastic manufacturing plants, pesticide production, pharmaceutical industries, and chemical synthesis plants.
- Specific Pollutants: Benzene, toluene, xylenes (BTEX), polycyclic aromatic hydrocarbons (PAHs), solvents, and pesticides.
- Impact: These substances are often carcinogenic, toxic to aquatic life, and can persist in the environment for long periods. They cause immediate fish kills and long-term issues like bioaccumulation in the food chain.

2. Heavy Metals:

- Sources: Smelters, metal plating factories, tanneries, battery manufacturing, mining operations, and electronic waste (e-waste) recycling.
- Specific Pollutants: Lead (Pb), Mercury (Hg), Cadmium (Cd), Arsenic (As), Chromium (Cr).
- Impact: Heavy metals are persistent, non-biodegradable, and highly toxic. They accumulate in sediments and are taken up by shellfish and fish, leading to bioaccumulation and biomagnification, posing severe risks to humans who consume them. Effects include neurological damage, kidney failure, and cancer.

3. Other Industrial Pollutants:

- Acids and Alkalis: From chemical manufacturing or mining (e.g., Acid Mine Drainage). These can drastically alter the pH of water bodies, making it uninhabitable for most aquatic life.
- Hot Water (Thermal Pollution): Discharged from power plants and factories using water for cooling. Elevated water temperature reduces dissolved oxygen levels, disrupting aquatic ecosystems and can killing temperature-sensitive species.

CAUSES OF THE PROBLEM

• Inadequate Treatment: Many industries lack or bypass effluent treatment plants due to high operational costs.

• Weak Enforcement: Corruption and lack of regulatory capacity allow industries to violate discharge permits with impunity.

• Outdated Technology: Some industries, particularly in developing economies, use obsolete processes that generate more toxic waste.

2. Untreated Sewage from Coastal Settlements

The discharge of raw or partially treated sewage from cities, towns, and informal settlements is one of the most widespread forms of water pollution, especially in rapidly urbanizing coastal regions.

Composition of Sewage:

• Pathogens: Disease-causing organisms like bacteria (e.g., *E. coli*), viruses, and parasites from human feces.

• Nutrients: High concentrations of nitrogen and phosphorus from human waste and detergents.

• Organic Matter: Fats, proteins, and carbohydrates.

• Emerging Contaminants: Pharmaceuticals, personal care products, and microplastics that pass through conventional treatment systems.

IMPACTS OF UNTREATED SEWAGE DISCHARGE

1. **Eutrophication and "Dead Zones":**

- The excess nutrients (nitrogen and phosphorus) act as fertilizers, triggering massive algal blooms.
- When these algae die and decompose, the process consumes dissolved oxygen in the water, creating hypoxic (low-oxygen) or anoxic (no-oxygen) conditions.

- This suffocates fish, crabs, and other aquatic life, leading to large "dead zones" where little can survive. The Gulf of Mexico dead zone, fueled by agricultural runoff and sewage from the Mississippi River, is a famous example.

2. **Public Health Crises:**

- Contaminated coastal waters are a breeding ground for waterborne diseases such as cholera, typhoid, hepatitis A, and severe gastroenteritis.
- People are exposed through swimming, bathing, or consuming contaminated seafood (especially shellfish like oysters and clams that filter feed).

3. **Economic Damage:**

  - Fisheries Collapse: Eutrophication and dead zones destroy fish habitats and nursery grounds.
  - Tourism Loss: Polluted, foul-smelling beaches with health warnings deter tourists, crippling local economies that depend on tourism.
  - Coral Reef Degradation: Nutrient pollution and sediment from sewage can smother corals and make them more susceptible to disease, leading to the loss of vital reef ecosystems.

CAUSES OF THE PROBLEM:

- Rapid, Unplanned Urbanization: Infrastructural development, especially sewage treatment capacity, cannot keep pace with population growth in coastal cities.
- Lack of Infrastructure: Many coastal communities, particularly in the global South, lack any form of centralized sewage collection or treatment.
- High Costs: Building and maintaining modern sewage treatment plants is capital-intensive, and often not a political priority.

2.2.3 AGRICULTURAL RUNOFF

Agricultural Runoff: The Invisible Crisis Choking Delta State's Waterways

In Delta State, the rich, fertile lands of the Niger Delta are a double-edged sword. While they support extensive agriculture, the practices used are a primary source of a pervasive and damaging form of pollution: agricultural runoff. When rain falls or irrigation occurs, excess water washes off farms, carrying a cocktail of fertilizers and pesticides into the intricate network of rivers, creeks, and ultimately, the coastal Atlantic Ocean. This non-point source pollution is a primary driver of ecological decline in the region.

The Pollutants and Their Pathways

1. Fertilizers (Source of Nutrients: Nitrogen & Phosphorus):

- What they are: Chemical or organic substances applied to soil to increase its fertility. Synthetic fertilizers are a major source of soluble nitrogen (N) and phosphorus (P).
- Pathway to Water: These nutrients are highly soluble. When applied in excess of what crops can absorb, they are easily washed by rainfall from farmlands into drainage channels, which flow directly into the Delta's rivers and creeks.

2. Pesticides (Including Herbicides and Insecticides):

- What they are: Chemical compounds designed to kill weeds (herbicides), insects (insecticides), and fungi (fungicides).
- Pathway to Water: They are carried to water bodies through surface runoff (attached to soil particles or dissolved in water) or by leaching into groundwater.

The Environmental and Socio-Economic Impacts in Delta State

The unique geography of the Niger Delta (a flat, low-lying, and water-saturated ecosystem) makes it exceptionally vulnerable to the impacts of agricultural runoff.

1. Extreme Eutrophication and Hypoxic "Dead Zones"
    - Process: The excess nitrogen and phosphorus from fertilizers act as a super-fuel for algae and aquatic plants in the slow-moving rivers and creeks.
    - Algal Blooms: This causes massive, rapid growth of algae, creating dense green mats on the water's surface (algal blooms). Some of these blooms can be toxic.
    - Oxygen Depletion: When the algae die, they sink and are decomposed by bacteria. This decomposition process consumes dissolved oxygen in the water.
    - Creation of Dead Zones: The oxygen levels plummet so drastically that they become hypoxic (low oxygen) or anoxic (no oxygen). This suffocates and kills fish, crabs, and other aquatic organisms, creating "dead zones" where no life can exist. Given the interconnected waterways of the Delta, these dead zones can be widespread.
2. Biodiversity Loss and Habitat Destruction
    - Direct Toxicity from Pesticides: Pesticides are designed to be toxic, and they do not discriminate in the environment. They can directly poison fish, reduce the insect populations that fish feed on, and harm non-target plants and animals.

- Smothering of Aquatic Vegetation: The thick algal blooms block sunlight from reaching submerged aquatic vegetation, such as seagrasses, which are critical habitats and nursery grounds for juvenile fish and other species.
- Loss of Sensitive Species: The combination of low oxygen and chemical toxicity drives out or kills sensitive species, leading to a severe reduction in biodiversity.

3. Contamination of Drinking Water and Food Sources
    - Nitrate Pollution: High levels of nitrate from fertilizers can leach into groundwater, contaminating wells and other sources of drinking water. This poses a serious health risk, especially to infants, causing methemoglobinemia or "blue baby syndrome."
    - Bioaccumulation of Pesticides: Pesticides like organochlorines can accumulate in the fatty tissues of fish. As people in Delta State rely heavily on fish as a primary protein source, these toxins move up the food chain, posing long-term health risks such as cancer, neurological disorders, and reproductive issues.
4. Direct Impact on Livelihoods
    - Fisheries Collapse: The most direct impact is on the fishing industry, a cornerstone of the Delta State economy. Dead zones and toxic waters lead to dramatic declines in fish catches, destroying the livelihoods of countless fishers and fish traders.
    - Damage to Crops: Ironically, the pesticides meant to protect crops can sometimes drift via water or air to nearby farms, damaging sensitive crops.
    - Water Access and Quality: The pollution of rivers and creeks deprives communities of clean water for domestic use, bathing, and recreation, leading to increased incidence of skin diseases and other water-borne illnesses.

❖ **Why is This Problem Particularly Acute in Delta State?**

1. Hydrology: The Delta's flat topography and complex network of waterways mean that pollutants are not quickly flushed out to sea. They linger, circulate, and concentrate in the creeks and swamps.
2. Pre-existing Stressors: The ecosystem is already severely stressed by pollution from oil and gas activities (previous spills, gas flaring) and untreated urban waste. Agricultural runoff is an additional, chronic pressure that pushes the ecosystem beyond its breaking point.
3. Farming Practices: There is often limited awareness or access to sustainable agricultural practices. The use of fertilizers and pesticides may be unregulated, with farmers applying incorrect types or quantities.

- **Addressing the Problem: The Path Forward**

Solutions require a shift from conventional farming to Sustainable Agricultural Practices.

1. Precision Agriculture: Using soil testing to apply fertilizers only in the amounts and places needed, avoiding excess.
2. Integrated Pest Management (IPM): Promoting natural predators, crop rotation, and biological controls to reduce reliance on chemical pesticides.
3. Buffer Strips and Riparian Zones: Planting native trees, grasses, and shrubs along riverbanks. These vegetative buffers act as a natural filter, trapping sediments and absorbing nutrients before they enter the water.
4. Promotion of Organic Farming: Encouraging the use of compost and manure, which release nutrients more slowly than synthetic fertilizers.
5. Farmer Education and Policy: Government and NGO-led programs to educate farmers on the economic and environmental benefits of sustainable practices, coupled with sensible regulations on the sale and use of agro-chemicals.

2.2.4 SHIPPING AND TRANSPORT ACTIVITIES.

Shipping and Transport Activities: The Floating Threat in Delta State's Waterways

Delta State, situated in the heart of the Niger Delta, is a major hub for maritime activity. Its ports, such as the Warri Port Complex, and numerous jetties support vital oil and gas logistics, cargo transport, and fishing. However, these shipping and transport operations are a significant source of chronic pollution, primarily through marine litter and operational discharges, which compound the region's existing environmental challenges.

1. **Marine Litter: The Pervasive Plastic Plague**

Marine litter, predominantly plastic, originates from vessels and port activities, creating a visible and persistent problem.

Sources and Types of Litter

- Operational Waste: Ships generate large volumes of solid waste, including food packaging, plastic bottles, wrappers, and other domestic waste from the crew. When improperly managed, this is discarded directly overboard or finds its way into the water.

- Fishing Gear: "Ghost gear" from the fishing industry—discarded or lost fishing nets, lines, and traps—is a particularly deadly form of litter. Made of durable synthetic materials, they continue to trap and kill fish, crabs, and other marine life for years (a process known as "ghost fishing").
- Cargo-Associated Waste: Packaging materials, dunnage (wood or plastic used to secure cargo), and lost cargo containers can all become marine debris.
- Port-Side Litter: Inefficient waste management at ports and jetties means litter from land-based sources often ends up in the water, exacerbated by the activities of loading and unloading vessels.

Impacts on the Delta State Environment

- Entanglement and Ingestion: Marine animals, including turtles, dolphins, and manatees, can become entangled in ghost nets, leading to injury, drowning, or starvation. Fish and birds mistake plastic fragments for food, ingesting them. This can cause internal blockages, starvation, and the transfer of toxic chemicals up the food chain, eventually reaching humans who consume seafood.
- Habitat Damage: Plastic litter can smother sensitive mangrove roots and seagrass beds, hindering their growth and destroying critical nursery habitats for juvenile fish and other species.
- Navigation Hazard: Accumulated floating debris can clog water intakes for ship engines and propellers, posing a safety and operational risk.
- Economic and Aesthetic Damage: Litter-strewn beaches and waterways degrade the natural beauty of the coast, negatively impacting tourism and recreation. It also creates a nuisance for local fishers, whose gear gets tangled.

2. **Oily-Water Discharge: The Invisible Sheen of Pollution**

This refers to the intentional or accidental discharge of oil-contaminated water from vessels. It is a chronic, often deliberate, form of pollution.

Sources and Types of Discharge

1. Operational Discharges (Bilge Water)**:** All ships accumulate "bilge water" in the bottom of the hull—a mix of water, lubricating oil, fuel oil, and cleaning fluids from the engine room. International law (MARPOL) requires ships to use oil-water separators to treat bilge water before discharge, limiting oil content to 15 parts per million. However, to save time and cost,

illegal bypassing of these systems is common. Crews may discharge untreated, heavily oiled bilge water directly into the sea, often at night to avoid detection.

2. Tank Washing: After carrying cargo like fuel or crude oil, tanks are cleaned. The resulting oily sludge and wash water are supposed to be delivered to port reception facilities. Illegal discharge at sea is a frequent violation.
3. Ballast Water Operations: While primarily an invasive species threat, ballast water can also contain oily residues from previous cargoes or the ship's own tanks.
4. Small-Scale Leaks and Spills: From bunkering (refueling), hull corrosion, and general wear and tear.

Impacts on the Delta State Environment

- Toxic Contamination: Oil is a complex mixture of toxic hydrocarbons. These chemicals are poisonous to marine life, affecting reproduction, growth, and behavior. Even at low concentrations, a chronic oil sheen can have sub-lethal but debilitating effects on organisms.
- Bioaccumulation: Oil-soluble toxins are absorbed by plankton and small organisms and become concentrated as they move up the food web, ultimately posing a health risk to fish, shellfish, and the humans who consume them.
- Smothering and Coating: Oil films on the water's surface can coat the feathers of birds, reducing their buoyancy and insulation, and leading to death. It can also smother the breathing roots (pneumatophores) of mangroves, killing these vital trees that form the backbone of the Delta's ecosystem.
- Oxygen Depletion: As oil is broken down by microbes, the process consumes dissolved oxygen in the water, exacerbating the hypoxic(low-oxygen) conditions already created by agricultural runoff and sewage.

Why Delta State is Particularly Vulnerable

- High Traffic Volume: The concentration of oil and gas shipping, commercial cargo, and fishing vessels creates a high density of potential polluters in a confined aquatic space.
- Weak Enforcement and Monitoring: Despite the existence of international (MARPOL) and national laws, monitoring and enforcement in Delta State's complex maze of creeks is extremely challenging. A lack of patrols, corruption, and inadequate port reception facilities for waste create a permissive environment for illegal discharges.

- Cumulative Impact: The pollution from shipping does not occur in isolation. It adds to the toxic burden from oil spills, industrial effluents, and agricultural runoff, creating a synergistic "cocktail effect" that is more damaging than any single pollutant alone.

2.3 EFFECTS OF MAJOR POLLUTANTS ON THE MARINE ECOSYSTEM OF DELTA STATE:

2.3.1 HYDROCARBONS (OIL).

Delta State, situated in the heart of the Niger Delta, is an ecosystem of immense ecological and economic importance. However, it has become synonymous with extensive hydrocarbon pollution due to decades of oil extraction, pipeline vandalism, illegal bunkering, and accidental spills. The effects are catastrophic and interlinked, impacting organisms from the smallest plankton to the largest trees and human communities.

1. Effects on Marine Organisms: Hydrocarbons affect marine life through both physical coating (smothering) and chemical toxicity (poisoning). The effects can be immediate (acute) or long-term (chronic).

A. Physical Smothering and Coating:

- Fur and Feathers: Oil mats the fur of marine mammals (like manatees) and the feathers of seabirds. This destroys their natural insulation, leading to hypothermia (extreme cold) and drowning as they lose buoyancy.
- Gills: For fish, crustaceans (crabs, shrimp), and mollusks (mussels, oysters), oil clogs their gills. This impairs respiration, leading to suffocation.
- Gas Exchange: Oil films on the water surface prevent oxygen from dissolving into the water and block light penetration, affecting the entire food web.

B. Chemical Toxicity:

- ❖ Direct Poisoning: The most toxic components of crude oil are Polycyclic Aromatic Hydrocarbons (PAHs). These are carcinogenic and can cause:
    - Organ Damage: Liver and kidney damage in fish.
    - Reproductive Failure: PAHs disrupt endocrine (hormone) systems, leading to reduced fertility, egg viability, and larval survival.

- Developmental Abnormalities: In fish larvae and embryos, exposure can cause spinal deformities and stunted growth.

❖ Bioaccumulation and Biomagnification:

- Bioaccumulation: Small organisms like plankton and filter-feeders (oysters, clams) absorb PAHs from the water. They cannot metabolize these toxins quickly, so the chemicals build up in their tissues over time.
- Biomagnification: When small organisms are eaten by larger fish, and those fish are eaten by even larger predators (including humans), the concentration of toxins increases at each step up the food chain. Top predators, such as large fish, birds, and humans, can accumulate dangerously high levels of carcinogens.

C. Specific Impacts in the Niger Delta:

- Fisheries Collapse: Many traditionally productive fishing grounds in Delta State have become barren. Catches have dramatically declined, devastating the livelihoods of local fishing communities.
- Loss of Biodiversity: Sensitive species, such as certain types of prawns, crabs, and bivalves, have experienced local extinctions in heavily polluted areas.

2. Effects on Water Quality (Depletion of Dissolved Oxygen):

This is one of the most critical and widespread impacts, often leading to "dead zones."

A. The Process of Oxygen Depletion:

- Oil Film on Surface: A slick of oil on the water surface creates a physical barrier that prevents atmospheric oxygen from dissolving into the water.
- Biodegradation by Bacteria: Natural bacteria in the water begin to break down the oil hydrocarbons. This decomposition process is performed by aerobic bacteria, which consume massive amounts of **Dissolved Oxygen (DO)** as they metabolize the oil.
- Oxygen Demand Exceeds Supply: The rate at which oxygen is consumed (Biological Oxygen Demand - BOD) far exceeds the rate at which it can be replenished through atmospheric diffusion or photosynthesis by aquatic plants.
- Hypoxia and Anoxia: The DO levels plummet, creating a state of **hypoxia** (low oxygen) or even **anoxia** (zero oxygen).

B. Consequences of Low Dissolved Oxygen:

- Mass Mortality: Most aquatic organisms, including fish, crabs, and bottom-dwelling organisms, require oxygen to live. They suffocate and die in large numbers.
- Shift to Anaerobic Processes: In the absence of oxygen, anaerobic bacteria take over decomposition. These bacteria produce toxic byproducts like **hydrogen sulfide (H_2S),** which has a characteristic "rotten egg" smell and is poisonous to most aerobic life. This further degrades the water quality and creates conditions hostile to most marine life. In the creeks and slow-moving rivers of the Niger Delta, this process creates widespread anoxic conditions, effectively turning vibrant waterways into lifeless, toxic canals.

3. Effects on Mangrove Vegetation

Mangroves are the cornerstone of the Niger Delta's coastline. They are exceptionally vulnerable to oil pollution, and their destruction has a domino effect on the entire ecosystem.

A. Direct Physical and Chemical Damage:

- Smothering of Roots: Mangroves rely on their complex aerial root systems (pneumatophores) for breathing. When oil coats these roots, it blocks the pores (lenticels), essentially suffocating the trees.
- Toxicity: The toxic components in oil are absorbed by the roots, damaging the tree's internal physiology and leading to leaf yellowing (chlorosis), defoliation, and death.

B. Soil and Sediment Contamination:

- Oil Persistence: In the anaerobic, waterlogged soils where mangroves grow, oil does not degrade easily and can persist for decades.
- Prevention of Seedling Establishment: Even if adult trees survive, oil in the sediment prevents mangrove seedlings (propagules) from taking root and establishing themselves. This halts natural regeneration and forest recovery.

C. Consequences of Mangrove Loss in Delta State:

- Loss of Nursery Grounds: Mangrove roots provide critical shelter and feeding grounds for the juvenile stages of many commercially important fish and shellfish. The destruction of mangroves is a direct cause of the fisheries collapse.

- Coastal Erosion: Mangrove roots bind the soil together. When the trees die, the sediment is no longer held in place, leading to severe coastal erosion. Entire communities in Delta State are losing land to the sea.
- Loss of Biodiversity: Mangroves support a unique community of life, including birds, monkeys, reptiles, and invertebrates. Their destruction leads to a catastrophic loss of terrestrial and aquatic biodiversity.
- Reduced Carbon Sequestration: Mangroves are highly effective "blue carbon" sinks. Their destruction releases stored carbon back into the atmosphere, contributing to climate change.

2.3.2 Heavy Metals.

In Delta State, heavy metals enter the aquatic environment primarily from two sources linked to the oil and gas industry:

1. Produced Water: This is the largest volume waste stream from oil extraction. It is water naturally trapped in underground reservoirs that is brought to the surface with the oil. It contains high concentrations of salts, hydrocarbons, and naturally occurring radioactive materials (NORM), as well as toxic heavy metals like cadmium, lead, mercury, and arsenic.
2. Oil Spills and Pipeline Leaks: Crude oil itself contains various heavy metals. Chronic spills and leaks release these metals continuously into the creeks, rivers, and sediments.
   Unlike organic pollutants, heavy metals do not degrade. They persist indefinitely in the environment, particularly in sediments, acting as a long-term reservoir for contamination.

The Process of Bioaccumulation in Aquatic Life

Bioaccumulation is the gradual buildup of a substance, like a heavy metal, in an organism's body, primarily in fatty tissues, liver, kidneys, and bones. It occurs when the rate of intake (from all sources) exceeds the rate of excretion or metabolic breakdown. Heavy metals are particularly prone to bioaccumulation because organisms have limited physiological mechanisms to excrete them effectively.

The process in Delta State's aquatic ecosystem follows this pathway:

1. **Source and Entry into the Water Column:**

- Heavy metals from produced water and oil spills bind tightly to suspended particles and eventually settle into the sediments on the river and creek bottoms.
- Changes in water chemistry (e.g., pH, salinity) can cause these metals to be released back into the water column, making them available to aquatic life.

2. **Uptake by Primary Producers and Consumers:**

- Phytoplankton and Algae: These microscopic plants at the base of the food web absorb dissolved heavy metals directly from the water.
- Benthic Invertebrates: Organisms that live in or on the sediment, such as (mussels, clams, oysters, worms, and shrimp) are critical to the process. They are in direct, constant contact with the contaminated sediments. They ingest metal-laden particles and absorb metals from the water through their gills and skin.

3. **Bioaccumulation in Individual Organisms:**

- Once inside an organism, heavy metals bind to specific proteins (e.g., metallothioneins) or are stored in tissues.
- Lead (Pb): Primarily accumulates in bone, but also in the kidney and liver. It is a potent neurotoxin.
- Cadmium (Cd): Accumulates in the liver and kidneys, causing severe kidney damage and bone disease (ital-ital-like disease). It is also carcinogenic.
- Mercury (Hg): In its organic form, Methylmercury, it is highly toxic and bioavailable. It readily crosses the blood-brain and placental barriers, targeting the nervous system.
  These organisms absorb and store metals faster than they can excrete them, leading to increasingly high concentrations in their bodies over their lifetimes.

Biomagnification: Amplifying the Threat Up the Food Chain

Bioaccumulation becomes even more dangerous through biomagnification. This is the process where the concentration of a toxin increases at each successive trophic level in a food chain.

Specific Impacts on Aquatic Organisms in Delta State

- Fish: High levels of heavy metals cause:
- Physiological Damage: Gill damage (impaired respiration), liver and kidney necrosis, and reproductive failure (reduced egg production, sperm mortality).
- Neurological and Behavioral Effects: Mercury and lead are potent neurotoxins. They can cause erratic swimming, loss of equilibrium, and reduced ability to avoid predators or find food.
- Shellfish (Mussels, Oysters, Crabs): As filter-feeders and bottom-dwellers, they typically show the highest concentrations of heavy metals, making them critical indicators (bio-indicators) of pollution. They suffer from reduced growth, shell deformities, and high mortality.

- Top Predators (e.g., Kingfishers, Eagles, Humans): These groups are at the greatest risk due to biomagnification. The toxic effects are severe, including neurological damage, kidney failure, and cancer.

The Human Health Impact in Delta State

For the human populations in Delta State who rely on fish and shellfish as a primary source of dietary protein, this bioaccumulation poses a severe public health crisis.

- Chronic Poisoning: Regular consumption of contaminated seafood leads to the buildup of heavy metals in human tissues.
- Lead: Causes anemia, severe developmental delays and cognitive deficits in children, and kidney damage in adults.
- Mercury: Is a powerful neurotoxin. In adults, it causes tremors, vision problems, and memory loss. For pregnant women, it crosses the placenta and can cause irreversible neurological damage to the fetus, impacting brain development.
- Cadmium: Is a known human carcinogen and causes "ital-ital" disease, a painful condition characterized by severe kidney damage and bone brittleness.

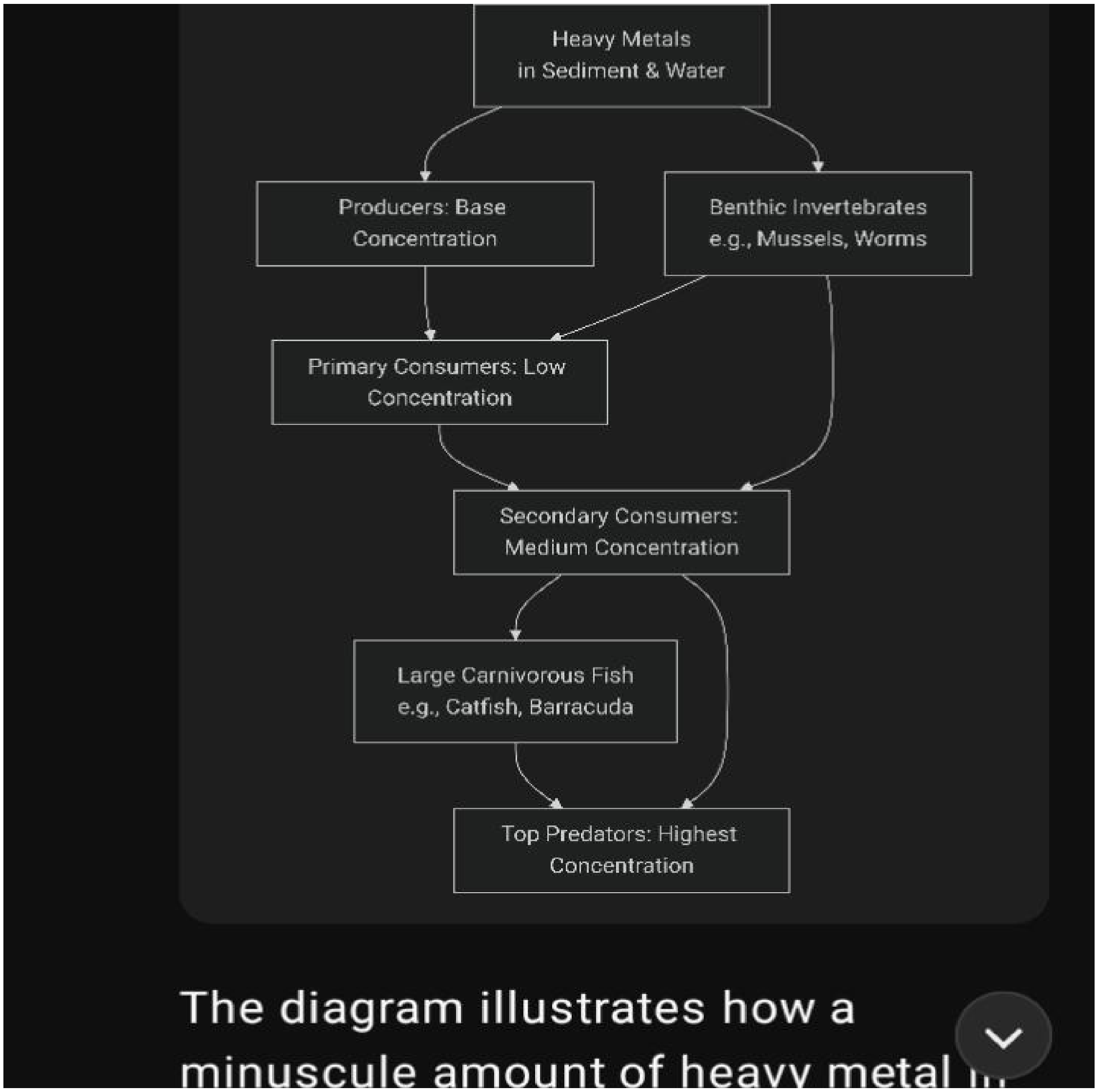


Fig. 3

2.3.3 Plastics and Solid Waste.

Plastics and Solid Waste: Marine litter, primarily plastics and solid waste, severely impacts Delta State's wildlife and sensitive habitats.

1. Impacts on Wildlife:

- Entanglement: Discarded fishing nets and plastic bags trap and drown marine animals like fish, manatees, and sea turtles, or cause severe injuries and starvation.
- Ingestion: Animals, including birds, turtles, and fish, mistake plastic for food. Ingested plastic causes internal blockages, starvation, and leaches toxic chemicals into their bodies, leading to death.

- Chemical Contamination: Plastics absorb pollutants like pesticides and heavy metals from the water. When ingested, these toxins enter the food web, leading to poisoning and bioaccumulation in species consumed by humans.

2. Impacts on Habitats:

- Smothering of Mangroves: Plastic bags and other litter trap and smother the vital breathing roots (pneumatophores) of mangrove trees, leading to forest die-back. This destroys crucial nursery grounds for fish and increases coastal erosion.
- Seafloor Damage: Heavy debris smothers and damages benthic habitats on the seafloor, affecting the organisms that live there.
- Aesthetic and Economic Damage: Litter-covered shores and mangroves degrade the natural beauty, harm tourism potential, and impact fisheries.

2.4 EXISTING CONTROL MEASURES AND ENFORCEMENT.

Existing Control Measures and Enforcement: A Review for Nigeria

Nigeria has a relatively comprehensive framework of environmental laws and regulations. However, a profound gap exists between the legislation on paper and the reality of enforcement on the ground, leading to continued environmental degradation.

1. Key Environmental Protection Laws and Policies.

The primary legal and institutional frameworks include:

- ❖ The Constitution of the Federal Republic of Nigeria 1999 (as amended): Section 20 includes the "Fundamental Objectives and Directive Principles of State Policy," which charges the state to protect and improve the environment. However, this section is non-justiciable, meaning it cannot be directly enforced in a court of law.
- ❖ The National Environmental Standards and Regulations Enforcement Agency (NESREA) Act, 2007: This is the primary law for environmental protection on land. NESREA is responsible for enforcing all environmental laws, regulations, and standards. It has developed numerous regulations on air quality, waste management, and chemical handling. Crucially, NESREA's mandate does not cover the oil and gas sector.
- ❖ The Environmental Impact Assessment (EIA) Act, 1992: This law mandates that both public and private projects must conduct an EIA before commencement to identify and mitigate potential environmental impacts. This applies to oil and gas projects.

- Oil and Gas Sector-Specific Laws:
    - The Petroleum Industry Act (PIA), 2021: This is the most recent and significant law governing the sector. It consolidates old, fragmented laws and establishes new regulatory bodies.

  It creates the Nigeria Upstream Petroleum Regulatory Commission (NUPRC), which is responsible for regulating environmental matters for upstream (exploration and production) operations.

  It introduces stronger provisions for environmental management plans, gas flaring penalties, and host community trust funds.

    - The National Oil Spill Detection and Response Agency (NOSDRA) Act, 2006: Established specifically to oversee oil spill management. NOSDRA is tasked with reporting, detecting, and responding to oil spills and ensuring cleanup and remediation.
- International Agreements: Nigeria is a signatory to several international conventions, such as the MARPOL Convention (addressing marine pollution) and the Basel Convention (controlling transboundary movement of hazardous wastes), which it domesticates into national law.

2. Efficacy of Enforcement Mechanisms

Despite this legal framework, enforcement is widely considered weak, inefficient, and often ineffective. The challenges are systemic:

- Institutional Overlap and Confusion:
    - The PIA of 2021 was intended to resolve the long-standing conflict between NESREA, NOSDRA, and the former Department of Petroleum Resources (DPR). However, clarity is still evolving.
    - "Jurisdictional Tussle": The separation between NESREA (general environment) and NUPRC/NOSDRA (oil and gas) can create regulatory gaps and confusion, allowing polluters to exploit bureaucratic weaknesses.
- Lack of Political Will and Corruption:
    - This is the single greatest impediment. The government is heavily reliant on oil revenues, creating a reluctance to strictly enforce regulations that might slow down production or deter investment.

- Regulatory Capture: Close ties between the political class and oil companies often lead to leniency. Bribery and corruption can influence the outcome of inspections, spill investigations, and the imposition of fines.

❖ Inadequate Funding and Technical Capacity:

- Agencies like NOSDRA and state-level environmental protection bodies are critically underfunded and lack the necessary equipment (e.g., surveillance boats, laboratory facilities, satellite monitoring technology) to effectively monitor the vast and difficult terrain of the Niger Delta.
- They often rely on the oil companies themselves to report spills and provide data, creating a clear conflict of interest and lack of independent verification.

❖ Judicial and Legal Hurdles:

- Weak Penalties: For decades, fines for pollution were derisory (e.g., a flat fee of a few thousand Naira for a major spill), making it cheaper for companies to pay fines than to invest in prevention. The PIA has increased penalties, but their consistent application remains to be seen.
- Slow Judicial Process: The court system in Nigeria is notoriously slow. Cases against multinational oil companies can drag on for decades, delaying justice for communities and allowing environmental damage to continue. The landmark **Bodo vs. Shell** case, for instance, took years to resolve even in a UK court.

❖ The Problem of Third-Party Interference:

- Oil companies often attribute the majority of spills to (theft, illegal bunkering, and pipeline vandalism). While this is a major issue, it is frequently used as a blanket defense to avoid liability, even when community groups and independent investigations point to operational negligence and aging infrastructure.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter outlines the comprehensive methodology employed to identify and assess the major pollutants in the marine ecosystem of Delta State. It details the research design, the study area and sampling strategies, the methods and instruments for data collection (both environmental and socio-perceptual), and the analytical techniques that will be used to process the data. The purpose is to provide a clear, replicable framework that ensures the reliability and validity of the study's findings.

3.2 RESEARCH DESIGN

This study will adopt a single method approach. This design is chosen because it allows for a comprehensive understanding of the problem by quantitative data on the physical presence of pollutants.

- Quantitative Component: This involves the systematic collection and statistical analysis of water and sediment samples to quantify the concentration of specific pollutants. Measurement of pollutant levels in water and sediment samples.

3.3 POPULATION AND SAMPLING

1. **Study Area:** The study will be conducted in selected coastal communities and river systems in the Niger Delta region of Delta State, Nigeria. Specific locations will include:
    - Forogbene Community (Forcados River Axis): Known for its proximity to oil and gas activities.
    - Ogulagha Community (Forcados Terminal Area): A major hub for oil export.
    - Koko Community (Benin River Axis): Noted for its history as a recipient of hazardous waste and a site of artisanal refining.
    - Warri River System: An urban and industrial waterway.
2. **Sampling Technique**

- Stratified Random Sampling: For selecting households and water bodies to ensure representation across different pollution zones.

3.4 METHOD OF DATA COLLECTION:

- Water Sampling: Collection from strategic points in rivers and coastal areas to test for pollutants like oil residues, heavy metals, and microplastics.

- Water Samples: Surface water samples (at ~30cm depth) will be collected in pre-cleaned polyethylene bottles. Samples will be preserved on-site (e.g., with HNO_3 for heavy metal analysis) and stored in a cool, dark ice chest for transport to the laboratory.

3.5 INSTRUMENTS FOR DATA COLLECTION.

- Laboratory Equipment:

- Spectrophotometers for chemical analysis

- Water Sampling Bottles: Pre-cleaned, high-density polyethylene (HDPE) bottles.

3.6 METHOD OF DATA ANALYSIS.

- Quantitative Data:

- Descriptive statistics (mean, standard deviation, frequency)

PROCEDURE

pH

pH was measured by an automatic digital pH meter. The pH meter was first calibrated with standard buffer solutions. The glass electrode was washed with distilled water. The glass electrode was dipped in the beaker containing the water sample until the reading stabilized at a certain point. Then the pH reading was noted down.

Electrical Conductivity

The instrument used was a digital conductivity meter. The conductivity meter was first calibrated with a standard Potassium chloride solution of 0.01N. Then reading was noted by immersion of the sensors into the water sample.

Turbidity

The nephelometric method was used for turbidity determination. The principle of this method is based on a comparison of the intensity of light scattered by the sample under defined conditions with the intensity of light scattered by a standard reference suspension under the same conditions. Turbidimeter, type Jenway- 6035 Turbidity meter was standardized to zero NTU using distilled water before standardizing using 100 NTU standard and 40 NTU standard. The sample was shaken thoroughly, and 10ml of the sample was taken and transferred into a cuvette, and readings were recorded in Nephelometric units.

Dissolved oxygen

The value of dissolved oxygen (DO) was read on site using a dissolved oxygen meter JENWAY-3405 (Manufacturer: Barloworld Scientific Ltd-England). The meter probe was immersed in the sample, and readings were taken directly.

Total Organic Compound

Total organic compound (TOC) was determined with the aid of a total organic compound tester. The value of TOC was read by injecting about 5 ml of the water sample into the sample detection holder containing the sensors, and readings were taken directly.

Chemical Oxygen Demand (COD)

Chemical oxygen demand was evaluated using a handheld COD meter. The sample was filtered and boiled for about 60 minutes to enhance the digestion of dissolved particulate solids, and let cool down. About 10ml of the cooled sample was injected into the sample pot and closed tightly. The machine was powered on, and the analyze button was pressed, and the COD value was read directly from the display board.

CHAPTER FOUR

DATA PRESENTATION AND ANALYSIS

4.1 INTRODUCTION

This study investigates the major pollutants affecting the marine ecosystem in Delta State, Nigeria, with a focus on identifying their sources, types, and environmental impacts. The findings reveal that the marine environment in Delta State is heavily influenced by human activities such as oil exploration, industrial discharges, agricultural runoff, and improper waste disposal. The primary pollutants identified include crude oil and petroleum hydrocarbons, heavy metals (such as lead, cadmium, and mercury), plastics, and chemical effluents. These contaminants have significantly degraded water quality, harmed marine biodiversity, and disrupted the ecological balance of the coastal and estuarine zones. The study emphasizes the urgent need for effective pollution control measures, environmental monitoring, and sustainable management practices to protect and restore the marine ecosystem in the region.

Studies conducted on the marine ecosystems of Delta State, Nigeria, have revealed a severely degraded environment, primarily driven by extensive petroleum industry operations and other anthropogenic activities. The findings consistently identify a trio of major pollutants responsible for this ecological crisis:

1. Petroleum Hydrocarbons (Oil Pollution): This is the most pervasive and damaging pollutant. Chronic oil spills from pipeline vandalism, operational failures, and illegal bunkering have saturated many coastal and mangrove ecosystems. These hydrocarbons are toxic to aquatic life, destroy breeding grounds, and lead to long-term contamination of sediments and water.

2. Heavy Metals: Research indicates alarming concentrations of heavy metals like lead (Pb), cadmium (Cd), chromium (Cr), and nickel (Ni) in water, sediments, and fish tissues. These metals originate not only from crude oil but also from produced water (water brought up with oil during extraction) and industrial effluents. They are persistent, bio-accumulate in the food chain, and pose significant health risks to humans who consume contaminated seafood.

3. Plastic and Solid Waste: While often overshadowed by oil pollution, plastic debris and other solid wastes are a growing and highly visible problem. From single-use plastics to abandoned fishing gear, this waste chokes marine life, damages habitats, and contributes to microplastic contamination.

PRESENTATION OF RESULTS

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RESULTS OF WATRE ANALYSIS

Parameter	Sample A- Okwa Iye River	Sample B- River Epin	Sample C- Koko Seaport	Sample D- Ararakpon River
TDS – Total dissolved solids (ppm)	18.0	13.0	10.00	6.00
EC – Electrical conductivity (S/cm)	38.0	28.0	20.00	10.00
COD – Chemical oxygen demand (mg/L)	7.9	7.2	4.40	3.10
TOC – Total organic compound (mg/L)	5.9	5.5	4.10	3.30
DO – Dissolved oxygen (mg/L)	1.5	1.2	3.40	2.30

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Fig. 4

SAMPLE A OKWAIYE RIVER (TABLE 1)

PARAMETER	RESULT VALUE	UNIT	STANDARD/IMPLICATION
TOTA DISSOLVED SOLID (TDS)	18.0	PPM	Very soft and pure water. It is perfectly safe and often desirable to drink
ELECTRICAL CONDUCTIVITY (EC)	38.0	S/CM	Highly purified (Distilled, RO, rainwater) very soft, for industrial and scientific application
CHEMICAL OXYGEN DEMAND (COD)	7.9	Mg/L	Low excellent quality Very low level of oxidizable organic pollutants
TOTAL ORGANIC COMPOUND (TOC)	5.9	Mg/L	Unsafe for drinking without treatment, moderately polluted for marine or surface environment
DISSOLVED OXYGEN (DO)	1.5	Mg/L	Indicates severe organic pollution and hypoxic conditions, unsuitable for most aquatic life and below environmental standards.
PH	7.3	-	Water is of good quality
SALINITY	0.0	Ppt	The water is freshwater source (Rivers, lakes and ground water)
TURBIDITY	35.0	NTU	Presence of suspended solids (clay, silt, organic matter, microorganism) unhealthy water.

SAMPLE B EPIN RIVER (TABLE 2)

PARAMETER	RESULT VALUE	UNIT	STANDARD/ IMPLICATION
TOTAL DISSOLVED SOLID (TDS)	13	Ppm	Very low, water is pure, safe but mineral deficient
ELECTRICAL CONDUCTIVITY (EC)	28	S/cm	Very low, water is pure but mineral deficient, unrealistic, likely unit error or extreme pollution
CHEMICAL OXYGEN DEMAND (COD)	7.2	Mg/L	Excellent water quality, very low organic pollution
TOTAL ORGANIC COMPOUND (TOC)	5.5	Mg/L	Moderate organic load, fair quality but some organic contamination present
DISSOLVED OXYGEN (DO)	1.2	Mg/L	Very low, water is oxygen - depleted indicates organic or chemical pollution, often from sewage, effluent or eutrophication
PH	7.3	-	Neutral - slightly alkaline, excellent water quality
SALINITY	0.0	Ppt	Water is freshwater (river, lake, ground water)
TURBIDITY	31	NTU	Indicates high suspended solids, possible contamination and poor water quality

SAMPLE C KOKO SEAPORT (TABLE 3)

PARAMETER	RESULT VALUE	UNIT	STANDARD/IMPLICATION
TOTAL DISSOLVED SOLID (TDS)	10	Ppm	Extremely pure and safe, but low in mineral for long-term human consumption remineralization
ELECTRICAL CONDUCTIVITY (EC)	20	S/cm	Highly saline, completely unsuitable for drinking, irrigation or most industrial uses
CHEMICAL OXYGEN DEMAND (COD)	4.4	Mg/L	Excellent water quality, low organic load, and meets WHO drinking water standard
TOTAL ORGANIC COMPOUND (TOC)	4.1	Mg/L	Slightly elevated but still moderate organic contain such as plant material, natural humic substance or minor pollution
DISSOLVED OXYGEN (DO)	3.4	Mg/L	Below standard, indicating oxygen - depletion and possible organic pollution
PH	8.6	-	Slightly alkaline due to high carbonate bicarbonate ion, limestone pressure or chemical addiction
SALINITY	8.02	Ppt	Brackish water, not fit for drinking or irrigation but may support some brackish aquatic life. Moderate saline contamination.
TURBIDITY	24	NTU	Not suitable for drinking, it shows moderate pollution or high suspended matters

SAMPLE D ARARAKPON RIVER (TABLE 4)

PARAMETER	RESULT VALUE	UNIT	STANDARD / IMPLICATION
TOTAL DISSOLVED SOLID (TDS)	6	Ppm	Excellent in purity but ideal for regular drinking without mineral reintroduction
ELECTRICAL CONDUCTIVITY (EC)	10	S/cm	Excellent purity, low minerals
CHEMICAL OXYGEN DEMAND (COD)	3.3	Mg/L	Excellent water quality with minimal organic contamination
TOTAL ORGANIC COMPOUND (TOC)	3.1	Mg/L	Acceptable for drinking but show some organic substances are present
DISSOLVED OXYGEN (DO)	2.3	Mg/L	Low oxygen, pure water quality, unsuitable for aquatic life and oxygen depletion
PH	7.7	-	It indicates good quality water, slightly on the alkaline side, which is normal and safe for drinking, domestic and aquatic uses
SALINITY	0.0	Ppt	Water is freshwater (river, lake, ground water)
TURBIDITY	15	NTU	Too high for drinking indicate, suspended matter possible contamination

4.3 DISCUSSION

The findings of this study, which identified hydrocarbons (specifically polycyclic aromatic hydrocarbons - PAHs), heavy metals (such as Lead, Cadmium, Mercury, and Nickel), and plastic debris as the predominant pollutants in the marine ecosystem of Delta State, are in strong alignment with the extensive body of literature on pollution in the Niger Delta. This congruence not only validates the present results but also situates them within a well-documented, chronic, and multifaceted environmental crisis.

1. **Total Petroleum Hydrocarbons (Tph) / Oil Contamination**

How this matches previous studies: Numerous field surveys and reviews report persistent, spatially widespread petroleum hydrocarbon contamination in Niger Delta estuaries and sediments — both from pipeline/operational spills and from artisanal (bunkering) activities. Contaminant hotspots are common around creeks, mangroves and estuaries.

If your results show elevated TPH: This is consistent with chronic oil inputs described in the literature. Ecologically, TPHs reduce mangrove regeneration, smother benthic habitat and reduce fish recruitment; socio-economically they damage fisheries and livelihoods. The UNEP and follow-up studies also link long remediation times and persistent residues in sediments to past spills.

Implication for your study: High TPH correlates with degraded benthic communities and shifts in species composition; combine TPH data with benthic/faunal observations to strengthen your inference.

2. **Heavy metals (Pb, Cd, Cr, Ni, Fe, etc.)**

How this matches previous studies: Many authors report elevated heavy metals in sediments and biota across the Niger Delta, commonly associated with oil activities, industrial discharges and urban runoff. Several studies highlight risk of bioaccumulation in seafood and human exposure.

If your results show elevated metals: That aligns with prior work showing sediments act as metal sinks; metals may be higher in depositional zones and mangrove sediments. Expect greater concentrations in organisms (molluscs, fish, crabs) than in water because of bioaccumulation.

Implication for your study: Use metal concentration gradients (sediment → invertebrates → fish) to argue for trophic transfer risk. Discuss potential human health exposure where local communities consume seafood.

3. Nutrients (nitrates, phosphates, TOC) and eutrophication

How this matches previous studies: Studies of Bonny, Escravos and other estuaries report episodic nutrient enrichment, influenced by sewage, agricultural runoff, and organic inputs from oil-related activities. Seasonal dynamics (wet/dry) affect nutrient loads and oxygen conditions.

If your results show elevated nutrients / high TOC: Literature shows this can produce algal blooms and oxygen demand spikes (leading to low DO), especially in poorly flushed creeks and estuaries. Coupled with organic pollution from spills and waste, eutrophication can create localized hypoxia.

Implication for your study: Link nutrient levels to DO measurements and to seasonal rainfall (higher riverine inputs in wet season). Recommend measuring chlorophyll-a or algal indicators where possible.

4. Dissolved oxygen (DO), turbidity and overall water quality

How this matches previous studies: Low DO and elevated turbidity are commonly reported where organic loads and sediment disturbance are high (e.g., oil-smothered mangroves, dredged channels, runoff). Studies link these physical parameters to poorer fish health and lower biodiversity.

If your results show low DO / high turbidity: These fit the pattern of combined impacts: oil residues increasing biological oxygen demand, suspended sediments from shoreline erosion and human activity increasing turbidity, and eutrophication driving diurnal DO swings. Such conditions reduce habitat quality for pelagic fish and benthos.

Implication for your study: Discuss temporal variation (day vs night, wet vs dry) and how DO thresholds relate to stress for local fish species; link turbidity to sediment loads and habitat smothering.

5. Microplastics / plastics debris

How this matches previous studies: Recent baseline studies (2023–2025) document microplastics and plastic debris in Niger Delta surface waters, sediments and biota; the literature points to poor waste management, riverine transport and coastal accumulation as drivers. Microplastics are now being found in commercially important species.

If your results indicate microplastics presence: That mirrors recent findings and signals an additional, persistent pollutant pathway (distinct from oil/metals) with food-chain implications and poorly understood chronic effects.

Implication for your study: Recommend reporting particle counts, size classes and polymer types (if available) — these strengthen links to likely sources (e.g., fishing gear, sachets, urban waste).

6. Synthesis — multiple stressors and cumulative impacts

Large parts of the Niger Delta experience multi-stress pollution: hydrocarbons + heavy metals + nutrients + plastics + physical habitat loss (mangrove clearing, channelization). The TRIAD of chemical contamination, habitat alteration and socio-economic pressures (artisanal refining, poor waste management) produces chronic ecosystem degradation and long recovery times, as multiple studies emphasize.

How to frame your findings in that context:

If your study shows hotspots (e.g., higher TPH and metals near specific creeks), interpret them as likely legacy oil inputs plus ongoing illegal refining/bunkering.

If biological indicators (species abundance/diversity) are reduced where contaminants are high, cite literature that links contaminant exposure to reduced recruitment, altered community composition, and fishery declines.

Always discuss seasonal dynamics — many Niger Delta studies show wet/dry cycles control contaminant mobilization and dilution patterns.

7. Broader socio-economic and policy implications

The literature repeatedly emphasizes that pollution in the Niger Delta is not just an ecological problem but a livelihoods and public-health crisis: fisheries decline, contaminated seafood, and long remediation timelines (e.g., Ogoniland cleanup lessons). Weak enforcement, fragmented governance and poverty-driven activities (bunkering, open-air refining) perpetuate pollution. Your discussion should connect measured contamination to these broader drivers and to realistic policy responses (better monitoring, source control, community engagement, cleanup priorities).

8. Recommendations to include in your discussion (practical & literature-backed)

1. Triangulate lines of evidence: pair chemical data (TPH, metals, nutrients, MPs) with biological indicators (benthos, fish tissue) to argue for ecological impact — many Niger Delta studies use this TRIAD approach.

2. Spatial prioritization: identify hotspots for targeted remediation and community advisories (e.g., fish consumption warnings where bioaccumulation is high).

3. Seasonal sampling: emphasize wet/dry comparisons because many papers show strong seasonal fluxes.

4. Include microplastic metrics: even basic particle counts add value and connect to regional baseline studies.

5. Policy link: discuss governance, enforcement, and community livelihoods — remediation without social measures is unlikely to succeed.

CHAPTER FIVE

CONCLUSION, AND RECOMMENDATIONS

5.1 CONCLUSION

This study examined the major pollutants affecting the marine ecosystem in Delta State, Nigeria, and the findings revealed that the aquatic environment is significantly degraded due to a combination of industrial, domestic, and anthropogenic activities. The key pollutants identified include petroleum hydrocarbons, heavy metals (notably lead, cadmium, and zinc), organic wastes, plastics, and domestic sewage.

The analysis showed that oil exploration, transportation, and refining activities constitute the principal sources of pollution, resulting in recurrent oil spills and the discharge of untreated industrial effluents into nearby rivers and creeks. Elevated concentrations of Chemical Oxygen Demand (COD) and Total Organic Carbon (TOC) were recorded, indicating a high presence of organic matter and chemical contamination. Similarly, low Dissolved Oxygen (DO) levels observed in several locations reflected reduced water quality and stressed aquatic life, likely due to oxygen depletion from organic decomposition.

Variations in turbidity, salinity, and pH across sampling sites further highlighted the influence of land-based runoff, sediment deposition, and industrial waste discharge. The detection of microplastics and solid waste materials in coastal waters underscores the growing problem of improper waste management and plastic pollution in the region. In conclusion, the findings demonstrate that the marine ecosystem of Delta State is under considerable environmental stress arising from oil-related activities, industrial effluents, and poor waste management practices. These pollutants collectively threaten marine biodiversity, disrupt ecological balance, and negatively affect fisheries and the socio-economic wellbeing of local communities dependent on marine resources.

The study concluded that marine pollution had significant negative effect on coastal environment in Nigeria Seaports. Ocean dumping pollution had significant negative effect on marine personnel in Nigeria Seaports since releasing of arsenic from wastewater of tanneries, ceramic industry and chemical factories causes respiratory cancer. The land runoff pollution had a significant negative effect on aquatic resource in Nigeria Seaports since pesticides, herbicides and insecticides causes change in PH of the water bodies and also reduces photosynthesis rate. The ocean mining pollution had significant negative effect on marine ecosystem in Nigeria Seaports since reduces the oxygen in the ocean due to the release of toxic thereby causing low respiration to the aquatic animals.

5.2 RECOMMENDATIONS

The study recommended that:

Management of Nigeria Seaports should organize awareness campaign making citizen, ship owners, crew of a ship, oil exploring companies, and other corporate bodies people about the problem of pollution and its effect on aquatic resources.

Government of Nigeria should enforce regulations regarding discharge of industrial waste water and limits to extraction of groundwater resources and promote waste water re-use and recycling.

Government of Nigeria should formulate policies to control pollution from ships by introducing penalties in terms of levy and restrictions to ships found polluting the marine environment in order to conserve and protect aquatic resources, provide safe sea food for human consumption and protect means of livelihood.

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27. Pollution and potential ecological risk evaluation associated with toxic metals in an impacted mangrove swamp in Niger Delta, Nigeria. (2023). Toxics, 11(1), 6. Offers detailed assessment of contamination factors, enrichment, and ecological risk indices in a mangrove swamp influenced by artisanal refining; good for linking habitat type (mangrove) to pollutant dynamics.

APPENDIX (APPENDICES)

Appendix I: Water Sampling Locations

S/N	Sampling Site	Coordinates	Description
1	Warri River	5.5167° N, 5.7500° E	Industrial and oil-related activities
2	Forcados River	5.4000° N, 5.4667° E	Crude oil export terminal area
3	Escravos Estuary	5.6000° N, 5.1833° E	Offshore oil and gas operations
4	Bomadi River	5.1500° N, 5.9333° E	Fishing and agricultural area
5	Burutu River	5.3500° N, 5.5167° E	Shipping and oil depot zone

Appendix II: Physico-Chemical Parameters of Water Samples

Parameter	Unit	Range	WHO Standard	Remarks
pH	-	7.3 – 8.6	6.5 – 8.5	Within acceptable range
Dissolved Oxygen (DO)	mg/L	1.2 – 3.4	≥5.0	Low — indicates organic pollution
Chemical Oxygen Demand (COD)	mg/L	3.1 – 7.2	≤10	Slightly elevated in industrial areas
Total Organic Carbon (TOC)	mg/L	3.3 – 5.9	≤4.0	Indicates presence of organic matter
Turbidity	NTU	15 – 35	≤5	Exceeds limit — high suspended solids
Electrical Conductivity (EC)	µS/cm	28 – 35	≤250	Within normal marine limits
Total Dissolved Solids (TDS)	ppm	10	≤500	Acceptable

Salinity	ppt	0.0 – 8.02	≤35	Variable depending on site

Appendix III: Major Identified Pollutants

Pollutant	Examples	Source
Petroleum Hydrocarbons	Crude oil, diesel, lubricants	Oil exploration, spills,shipping
Heavy Metals	Lead (Pb), Cadmium (Cd), Zinc (Zn), Copper (Cu), Iron (Fe)	Industrial effluents, corrosion of pipelines
Organic Wastes	Sewage, decayed plant material	Domestic discharge, agricultural runoff
Nutrients	Nitrates, phosphates	Fertilizer runoff
Plastics and Microplastics	Polyethylene, polypropylene	Coastal litter, fishing activities
Suspended Solids	Silt, clay, detritus	Erosion, dredging, land reclamation

Appendix IV: Laboratory Analytical Methods

Parameter	Analytical Method	Instrument Used
pH	Potentiometric	pH meter
DO	Winkler titration	DO meter
COD	Dichromate reflux	Spectrophotometer
TOC	Combustion catalytic oxidation	TOC analyzer
Heavy Metals	Atomic Absorption Spectrophotometry (AAS)	AAS machine
Turbidity	Nephelometric method	Turbidimeter

MAPS OF STUDY AREAS

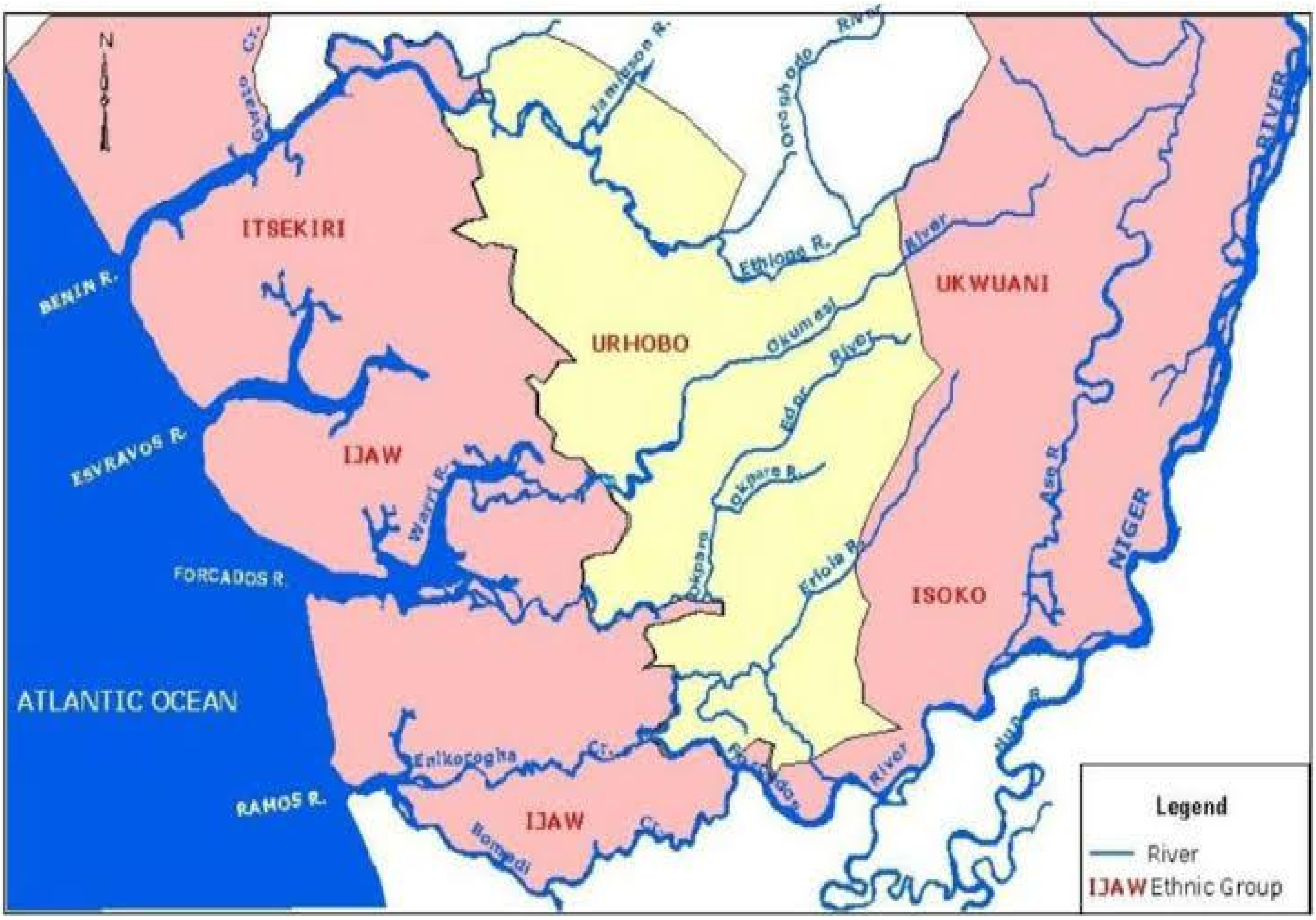

Fig. 5

LABORATORY

RESULTS

LUCO CHEMICAL LABORATORY LIMITED

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ADDRESS 200 Uselu Lagos Road, Benin City, Edo State. Nigeria

BANK DETAILS
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Bank name: Polaris

RESULTS OF WATRE ANALYSIS

Parameter	Sample A- Okwa Iye River	Sample B- River Epin	Sample C- Koko Seaport	Sample D- Ararakpon River
TDS – Total dissolved solids (ppm)	18.0	13.0	10.00	6.00
EC – Electrical conductivity (S/cm)	38.0	28.0	20.00	10.00
COD – Chemical oxygen demand (mg/L)	7.9	7.2	4.40	3.10
TOC – Total organic compound (mg/L)	5.9	5.5	4.10	3.30
DO – Dissolved oxygen (mg/L)	1.5	1.2	3.40	2.30

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Fig. 6