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Benthic Studies and Environmental Assessment in the Oil Producing Area of the Niger Delta

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Abstract The oceans of the world are divided into two areas; the benthic zone or seafloor environment and the pelagic zone or water environment. The continental slope and beyond make up the benthic zone and includes the deepest part of the ocean floor which are made up of sediments consisting of rock particles and organic remain such as calcium carbonate shells of small organisms. From the high-tide mark along the shore to the depths of the ocean are found plants and animals of the sea. Plant and animal life in the benthic zone is most abundant in the coastal waters on the continental shelf. The benthos lives on and depends on the sea bottom and includes benthic fauna like deposit and filter feeders such as barnacles, bryozoans, sponges, mussels, hydroids, pycnogonid sea spiders and stalked crinoids. Plants are found only in the epipelagic zone of the pelagic zone where there is enough light for photosynthesis. Light does not penetrate below the mesopelagic zone. Benthic organisms are good indicators of oil pollution because they live in the sediment for all or most of their lives with limited mobility and differ in their tolerance to amount and types of pollution. Much of the benthic ecosystem/habitat have been either lost or destabilized due to pollution resulting from exploration and production activities in the Niger Delta areas of Nigeria. The pollution could have been in the form of noise, heat and motion in addition to chemicals. It was discovered that the pollutions could have been prevented or properly assessed if the government had implemented all the guidelines concerning marine and land exploration and production activities through its agencies and if standard baseline reports from benthic studies carried out before the spills that could serve as references are available.

Keywords: *petroleum, pollution, benthic, sediment, pollution indicator, Niger Delta*

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1. Introduction

1.1. The Niger Delta

The Niger Delta, located in the southernmost part of Nigeria and covering an area of some 70,000 km^2, is the largest river delta in Africa and the third largest in the world (UNEP, 2011).

It is situated at the apex of the Gulf of Guinea on the west coast of Africa. The Niger Delta is home to more than 31 million people, and makes up more than 7.5% of Nigeria's land mass. It consists of 10 oil-producing states (Abia, Akwa Ibom, Anambra, Bayelsa, Cross River, Delta, Edo, Imo, Ondo, and Rivers) with more than 185 local government areas and over 800 oil-producing communities where a network of over 900 oil/gas producing wells are located (Aniefiok, E.I. et al, 2013). Mangrove forests and swamps with their complex and sensitive ecosystems are vital to the local economy and accommodate important fauna and flora (Ugochukwu, C.N.C. et al, 2008). For people in developing countries like Nigeria, especially in the Niger Delta, marine fisheries supported by ocean ecosystems are an essential source of protein. The Niger Delta is the largest mangrove forest in Africa, the thirst largest in the world, one of the world's largest tertiary delta systems and prolific hydrocarbon provinces, and richest part of Nigeria in terms of petroleum resources and diverse natural ecosystems.

1.2. Types of Pollution

Most environmental pollution is caused by human activities. Polluting materials are of two types; biodegradable (organic) pollutants which decompose rapidly by natural processes and nondegradable pollutants which decompose slowly or do not decompose in the natural environment (Smith, R.L., 2009).These nondegradable compounds bioaccumulate. Such dioxins, poly-chlorinated -biphenyls, DDT, and radioactive materials can reach dangerous accumulations as they are passed up the food chain. Noise, heat and motion are other forms or sources of pollution. For instance, contaminated sediments can act as reservoirs of pollution, releasing hydrocarbons when disturbed into the aquatic environment long after the original source of pollution has been removed due to the propeller action of a motorboat (UNEP, 2011). Sediment contamination poses one of the

most serious forms of environmental degradation within marine and estuarine ecosystems (Harriet, P. et al, 2010). Dredging also affects soils and sediments (Ohimain, E., 2004). Noteworthy is the fact that pollution effects can be separated into two categories: disturbance and stress.

1.3. Benthic fauna

Macrobenthic invertebrate fauna also referred to as bottom fauna, macro benthos or bottom dwellers are those animals that lack back-bones and are larger than 0.02-inch (size of a pencil dot). They live in benthic zones of lakes, ponds, rivers, seas, streams and either crawling, burrowing or attached to various kinds of solid objects like root of mangrove plants, stone rock, canoes, boat, sediment vegetation and wood during some period of their lives. Macrobenthic communities are ideal indicators of biotic integrity for many reasons: benthic organisms reside directly on or within sediments, where many contaminants are ultimately partitioned; benthic organisms are relatively sedentary, they cannot easily avoid contaminants; the macrobenthos occurs on the proper spatial scale for assessing anthropogenic impacts; and the temporal scale of their life histories enables the detection of chronic or historical environmental stress through signature effects on resident assemblages (Harriet, P et al, 2010). Because of their sensitivities to different contaminants, integrated responses by their assemblages reflect the severity and nature of environmental stressors. They include species of organisms which cut across different phyla which includes crustaceans like crayfish, molluscs such as snails, polychaetes like clam worms and aquatic insects such as aquatic wasps. Benthic studies are a direct assessment of the environmental health of landscapes which drain into them since rivers are at the receiving end of pollution effect of land use practices drained within their catchment (Igborbor, J.C. et al, 2004). Pollution on land is subsequently felt in marine environments through the effects of rain, wind, and surface or sub-surface flow. Rivers can therefore help in the environmental assessment of the landscapes that they drain (Dallas, H.F. et al, 1993). Ecosystem components are so interconnected that a change in any one component of an ecosystem (biotic or abiotic) will cause subsequent changes throughout the system. Biodiversity in an ecosystem provides essential medicines, foods and other necessary materials for human existence.

1.4. Regulatory Agencies

The federal Government of Nigeria has through its regulatory agencies tried to mitigate the effects of exploration, development and production of oil and gas on both the onshore and offshore environments since the first commercial oil discovery in the tertiary delta was confirmed at Oloibiri field in January 1956 by Shell D'Arcy which had monopoly of oil exploration (1938-1955). The environmental laws and regulations are the Oil Pipelines Act of 1956 (amended in 1965); Mineral Oils (Safety) regulations (1963); Oil in Navigable Waters Acts (1968); Petroleum Acts (1969); Associated Gas Re-injection Act (1979); the Federal Environmental Protection Agency (FEPA) Act (1988); the National Policy on the Environment, 1989 (revised in 1999); National Environmental Protection (Effluent Limitations) Regulations (1991); Environmental Protection (Pollution Abatement in Industries Generating Wastes) Regulations (1991); Environmental Impact Assessment (EIA) Act (1992); and the Department of Petroleum Resources (DPR) Environmental Guidelines and Standard for the Petroleum Industry in Nigeria (EGASPIN) (2002). Only some of these environmental regulations give guidelines on issues of petroleum pollution (Aniefiok, E.I. et al, 2013).

This review examines and compares the degradation on the Niger Delta's benthic environment based on the benthic studies and the environmental assessment on select locations where exploration and production of oil/gas and anthropogenic activities have had their direct impacts. Locations are in the states of Delta, Bayelsa and Rivers.

2. A Review of the Niger Delta System

2.1. Niger Delta Ecosystem

Unsustainable oil exploration activities has rendered the Niger Delta region one of the five most severely petroleum damaged ecosystems in the world (Kadafa, A.A. 2012). The impact of petroleum hydrocarbon on the environment depends on the organisms and their sensitivity to petroleum hydrocarbons. Hence, prediction of the impact of certain petroleum hydrocarbons requires site specific information on the receiving body. Susceptibility of organisms, population and ecosystems are dependent on the amount of toxic hydrocarbon in the petroleum hydrocarbon released since processes alter the chemical composition of the petroleum hydrocarbon which alters the toxicity (Kadafa, A.A. 2012).

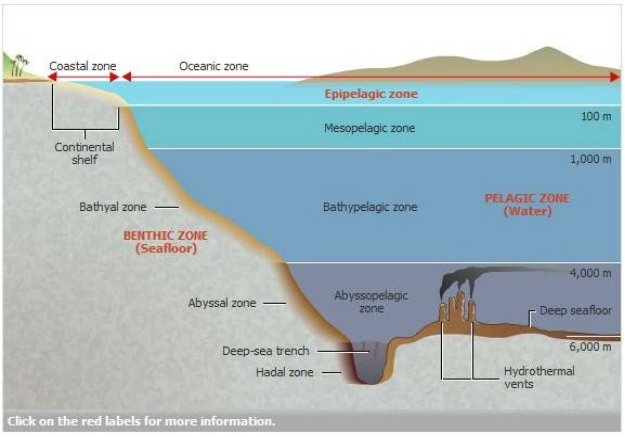

Figure 1. Life Zones of the Ocean (Source: Encarta Encyclopedia, 2009)

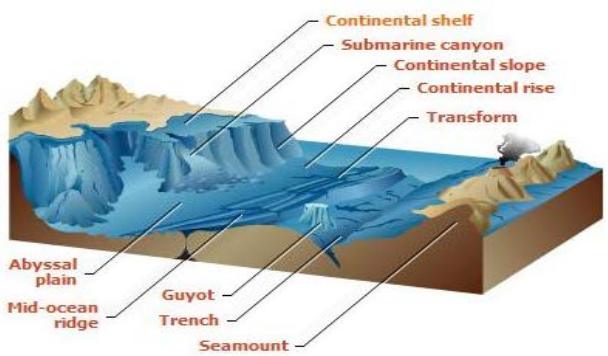

Figure 2. The Ocean floor. Most Offshore Drilling for Oil and Natural gas takes place in the Continental Shelves (Source: Encarta Encyclopedia, 2009)

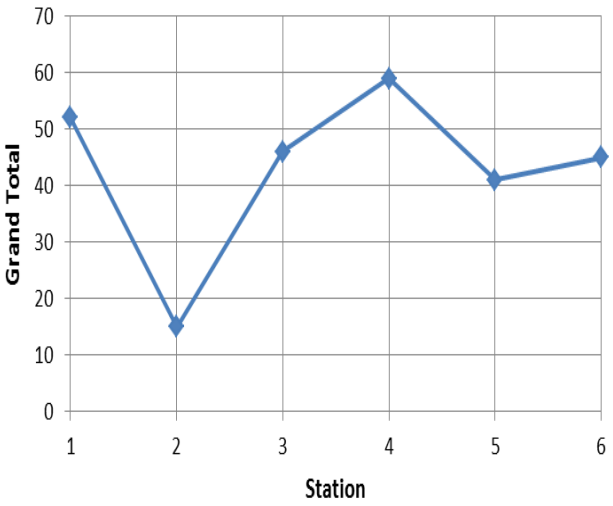

Figure 3. Total Abundance of Species per Station in Elechi Creek

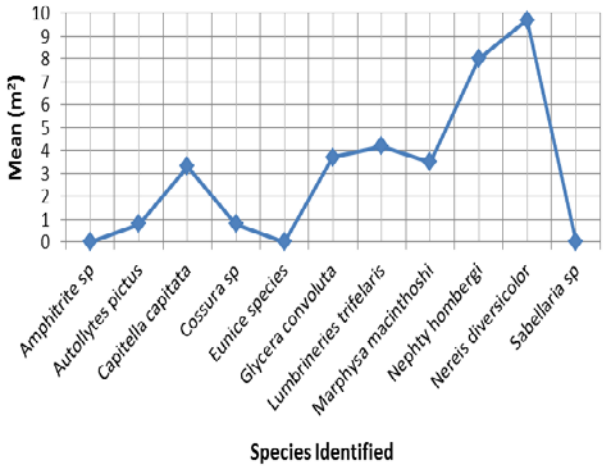

Figure 4. Mean values of Polychaetes identified

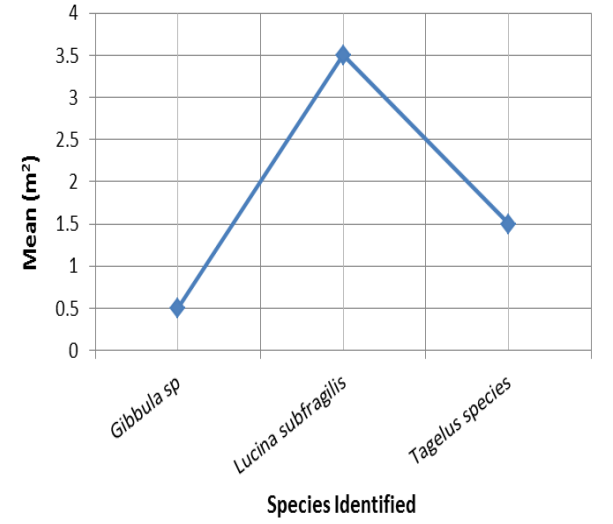

Figure 5. Mean values of Molluscs identified

2.2. Benthic Studies

Species types recorded in benthic infaunal communities seems to be comparable in the Niger Delta areas considered. There is usually poor occurrence of non-polychaete organisms. Since these non-polychaetes do not live in polluted environments, it is an indicator that the various areas of study are polluted. During EIA study of Diebu creek exploratory well, poor occurrence of the non-polychaete forms such as molluscs and shrimps was observed (SPDC, 2004). The presence of polychaetes is suggestive of organic waste pollution since they are used as pollution indicators. Macrobenthic study of Elechi creek (Figure 4, Figure 5, Figure 6, and Figure 7) showed that polychaetes populations were the dominant species followed by molluscs and crustaceans (Woke, G.N. et al, 2007). The faunal composition dominance of polychaetes in the brackish water station (Degema) is also attributable to their level of pollution tolerance (Abowei, J.F.N. et al, 2012). Polychaetes are abundant members of the bottom dwelling community from the shores to the ocean depths. Other biological indicators of pollution include Odonatans, Ephemenopterans and larval forms of Chironomids (Flora, E. et al, 2007).

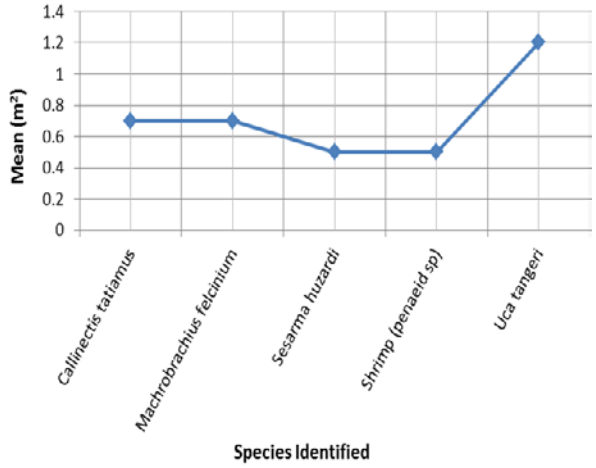

Figure 6. Mean values of Crustaceans identified

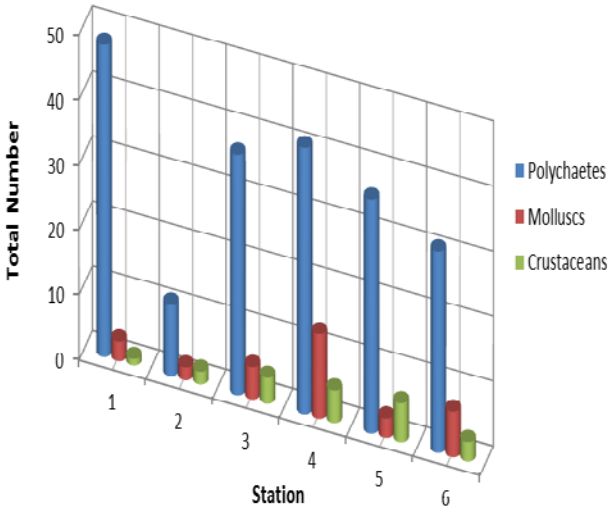

Figure 7. Comparison of Species per Station

2.3. Division of Petroleum Hydrocarbon

Basically, petroleum is mixture made up of hydrocarbon compounds, nitrogen, sulphur, oxygen, nickel, vanadium etc which can occur in solid, liquid or gaseous forms. The hydrocarbon components could be divided into saturates (pentane, hexadecane, octacosane, and cyclohexane), asphaltenes (phenols, fatty acids, ketones, esters, and porphyrins), aromatics (benzene, naphthalene, phenanthrene, and pyrene) and resins

(amides, carbazoles, pyridines, quinolones, and sulphoxides) (Ite, A.E. et al, 2012). Benzene, toluene, ethyl benzene and xylenes (BTEX), aliphatic and polycyclic aromatic hydrocarbons (PAHs) are the petroleum contaminants mostly found in soils and sediments because of their toxicity. Benzene is highly volatile and comparatively very soluble in ground water. Therefore, if it is not found in oil, it might be inhaled. Petroleum pollution in the Niger Delta of Nigeria contains complex mixture of both aromatic and aliphatic hydrocarbons (UNEP, 2011, Aniefiok, E.I. et al, 2013).

The higher molecular weight PAHs have been known to be carcinogenic, mutagenic and can bioaccumulate in organic tissues because they are lipophilic (Ite, A.E. et al, 2012), while the aromatic compounds can cause respiratory problems.

2.4. Sources of Pollution

Pollution sources could be natural or anthropogenic. The pollution is either related to gas flaring and venting, drilling discharges, dredging, spills (accidental or operational) discharges. Significant pollutants from the oil and gas industries are grouped under:

- Pollutants from exploration and production activities such as drilling muds, cuttings, oil and greases, salinity, sulphides, turbidity, suspended solids, temperature, pH, heavy metals, biological oxygen demand and COD
- Pollutants from refining activities such as greases and oil, COD, BOD, phenol, cyanide, sulphides, suspended solids, toxic additives, hydrocarbons and total suspended solids.

Offshore Niger Delta, while some of the oil would float (average density of 0.840, API 37), potentially, some could move into benthic sediments through multiple hypothesized pathways such as: sinking of oil and/or dispersed oil droplets adsorbed onto suspended particles, or incorporated into copepod fecal pallets, in either surface of sub-surface layers; onshore-offshore transport of oil-laden particles; sinking of heavier oil by-products resulting from the burning of oil; or settling of oil-mud complexes resulting from the injection of drilling mud during top-kill operations; and during blowouts (Deepwater Benthic Communities TWG, 2011).

Hydrocarbons can cause environmental consequences due to their chemical properties (e.g. toxicity) from light oils or physical properties (e.g. smothering) from heavy oils (UNEP, 2011, Kadafa, A.A., 2012). Benthic organisms are affected due to the smothering effects of thick oil in the coastline. Environmental consequences of crude oil may be felt on soil, water, vegetation, aquatic and terrestrial wildlife, and humans.

Table 1. Some Severely Oil Polluted Sites in the Niger Delta (Source; Kadafa, A.A. 2012)

LOCATION	ENVIRONMENT	IMPACTED AREA (ha)	NATURE OF INCIDENCE
BAYELSA STATE			
Biseni	Freshwater Swamp Forest	20	Oil Spillage
Etiama/Nembe	Freshwater Swamp Forest	20	Oil Spillage & Fire Outbreak
Etebelu	Freshwater Swamp Forest	30	Oil Spill Incidence
Peremabiri	Freshwater Swamp Forest	30	Oil Spill Incidence
Adebawa	Freshwater Swamp Forest	10	Oil Spill Incidence
Diebu	Freshwater Swamp Forest	20	Oil Spill Incidence
Tebidaba	Freshwater Swamp Forest/Mangrove	30	Oil Spill Incidence
Nembe creek	Mangrove Forest	10	Oil Spill Incidence
Azuzuama	Mangrove	50	Oil Spill Incidence
DELTA STATE			
Opuekebe	Barrier Forest Island	50	Salt Water Intrusion
Jones creek	Mangrove Forest	35	Spillage & Burning
Ugbeji	Mangrove	2	Refinery Waste
Ughelli	Freshwater Swamp Forest	10	Oil Spillage-Well head leak
Jesse	Freshwater Swamp Forest	8	Product leak/Burning
Ajato	Mangrove		Oil Spillage Incidence
Ajala	Freshwater Swamp Forest		Oil Spillage Incidence
Uzere	Freshwater Swamp Forest		Oil Spillage Incidence
Afiesere	Freshwater Swamp Forest		Oil Spillage Incidence
Kwale	Freshwater Swamp Forest		Oil Spillage Incidence
Olomoro	Freshwater Swamp Forest		QC
Ughelli	Freshwater Swamp Forest		Oil Spillage Incidence
Ekakpare	Freshwater Swamp Forest		Oil Spillage Incidence
Ughuvwughe	Freshwater Swamp Forest		Oil Spillage Incidence
Ekerejegbe	Freshwater Swamp Forest		Oil Spillage Incidence
Ozoro	Freshwater Swamp Forest		Oil Spillage Incidence
Odimodi	Mangrove Forest		Oil Spillage Incidence
Ogulagha	Mangrove Forest		Oil Spillage Incidence
Otorogu	Mangrove Forest		Oil Spillage Incidence
Macraba	Mangrove Forest		Oil Spillage Incidence
RIVERS			
Rumuokwurusi	Freshwater Swamp	20	Oil Spillage
Rukpoku	Freshwater Swamp	10	Oil Spillage

As a result of the large number of hydrocarbons present in crude oil, the health and particularly environmental impacts of the various constituents have not yet been fully understood. As a result, Environmental Impact Assessment (EIA) is carried out which is the assessment of the impacts of development projects on the ecological, physical, chemical, health, social and economic environments. It is a regulatory requirement for all major projects in Nigeria. Some severely oil polluted sites in the Niger Delta are shown in Table 1.

3. Comparison of the Niger Delta with Pollution Assessment in the Deep Water Horizon GoM Spill

Comparison of benthic studies in some states of the Niger Delta have been presented to highlight the importance of the use of pollution indicators in assessing environmental pollution from oil. A review of measures taken in other spill sites compared to the Niger delta has been considered. The pollution indicators popularly used are highlighted and as there are no (original) baseline data on benthic studies in the Niger delta, it would be difficult to express the level of damage when spills or pollution occur. The only reliable baseline information is from local Niger Delta communities fishermen who claim that the once highly abundant species like crustaceans have diminished.

3.1. Macondo Spill Responses as a Standard

The spill and impacts from the Deep water Horizon spill in April 2010 were quantified because there have been reference studies (pre-spill) at various locations on the benthic ecosystem of the Gulf of Mexico that served as baseline to ascertain the level of damage to the aquatic environment, particularly the benthic sediments and organisms (Deepwater Benthic Communities TWG, 2011).

Since organisms are assigned to groups according to the principles of taxonomy in the descending order of species-genus-family-order-class- and phylum, macrofauna from each of the samples was identified to lowest possible taxonomic level, particularly at the family level to increase the speed of analysis. This is also because very few species are known to the family level since there are many unknown species and benthic data at the family level have been shown to detect the same basic patterns as those developed to the species level. Therefore, since benthic responses to marine pollution suggests that macrofaunal and meiofaunal communities exhibit repeatable patterns of response to sedimentary contamination generally detectable at high taxonomic levels, even the phylum level, that biotic index was used. The level of awareness and the technology deployed in Macondo made the assessment easier and more accurate.

In one area around the Deep Water Horizon spill where red crabs were captured, there was wide assortment of polychaetes, crustaceans and larger foraminiferans (>500micrometer) which could serve as food (Harriet, P. et al, 2010), an appropriate use of pollution indicators to assess damage.

4. Discussion

Overall impacts on ecosystem/benthic indicator species

Indicator organisms are species picked for their sensitivity or tolerance to various parameters, historically pollution (Simboura, N. et al, 2002). The Niger Delta ecosystem has been affected adversely by the activities of the oil and gas companies in the area. It is observed that the polychaetes (tolerant or resistant species) are more than the molluscs and crustaceans (sensitive species) (Figure 4, Figure 5 and Figure 6). This is also evident in all the stations (Figure 7). Figure 9 shows the dominance of polychaetes over molluscs and crustaceans in the two states of Niger Delta. It is an indication that the entire Niger Delta area under study might have been polluted by the same pollution source. This is irrespective of the fact that other unknown factors might have contributed to the overall pollution observed. Polychaetes and oligochaetes (macrofauna) and foraminifera are usually used as pollution indicators of organic origin (Harriet, P. et al, 2010, Marieva, D. et al, 2010), though their utility are usually enhanced by baseline reports from the spill/polluted sites. The low presence of the non-polychaetes might be due to other reasons.

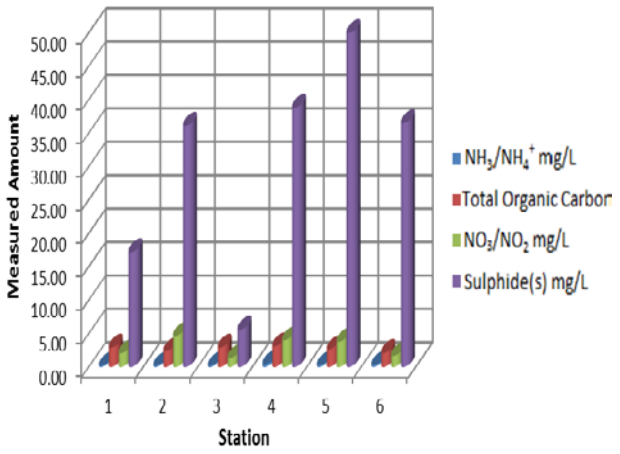

Figure 8. Variation of Parameters

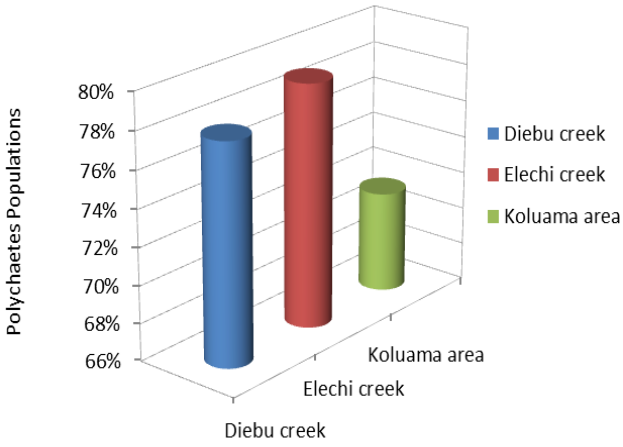

Figure 9. Dominance of Polychaetes in the Selected areas in the States of Bayelsa and Rivers.

Benthic studies need to be intensified in the Niger Delta as baseline reports are lacking. Freshwaters should be distinguished from brackish waters with high salinities, total solids and temperatures. During a spill or oil influx,

the main concern must be the source (using fingerprinting) and volume of oil spilled as well as turbidity and suspended solids content. Sea waters are known to contain trace metals in significant concentrations, so heavy metal composition is of lesser interest (Enujiugha, V.N. et al, 2004).

Some biotic indices used in pollution assessment include: BELLAN et al, 1981- use of families like cirratulids and paraonids; RAFFAELLI and MASON, 1981-ratio of nematodes/copepods; BELLAN, 1980-dominance of tolerant to pollution species as an Index of Pollution (IP); De BOER et al, 2001-r_strategy/k_strategy species; WORD, 1979-the Infaunal trophic Index i.e. use of formula involving feeding groups; WILSON et al, 1987-Biological Quality Index (BQI) plus Pollution Load Index (PLI); SATSMADJIS, 1982-Coefficient of Pollution (CoP); WARWICK and CLARKE, 2001; BORJA et al, 2000; and ROBERTS et al, 1998.

In Macondo spill, pre-spill baseline reports show that deep-sea red crab (*Chaceon quinquedens*) was the primary inhabitant of the continental slope in the northern Gulf of Mexico and was probably the major bioturbator. The crabs inhabit soft bottom areas and continuously filter fine sediment particles that are present in the bottom muds and the section of the water column adjacent to the sediment-water interface (Harriet, P. et al, 2010). They were hence expected to provide a useful diagnostic of organismal exposure to oil contamination of deep sea sediments. Then, following the spill, these organisms were much reduced or absent from two of the sites sampled in previous years since they are pollution sensitive despite the expected high presence of macrobenthic organisms that are pollution tolerant (resistant) and could have served as food. Generally, high diversity and numbers of macro-invertebrates indicate good water quality conditions whereas the presence of only pollution tolerant species or absence of macro-invertebrates suggests a degraded environment.

5. Conclusions

The distribution and diversity of aquatic organisms depends on water quality. Since the benthoses are needed for a balanced energy transfer in the food web, their existence must be guaranteed by ensuring safe and clean water. This is achieved by adopting the right environmental assessment practices using baseline reports.

The quality of the aquatic environment in terms of pollution expresses the level of health of the landscape and humans that empty into them. Benthic organisms exposed to poor quality water alter the community structure which requires time for balance to be restored in the ecosystem.

The steady apparent reduction in the amount of crustaceans (e.g. crayfish and crab) in the Niger Delta area which used to be plentiful could be attributed to the level of pollution in the area. Hence, it was discovered that baseline reports are lacking and should be developed by sampling the benthic population and their patterns with supernatant fluids in the Niger Delta locations that would be used in case of spills since gaps in sampling efforts exist. That reference report would answer the question of how polluted an area is. Taking samples along potential exposure gradients in different directions from an incident site has been shown to be a scientifically effective method for detecting long-term environmental impacts. Use of the biotic index applied in GoM to assess ecological quality using indicator organisms concept that take into account changes in taxa should be applied. For instance, bioindicators of contaminant exposure around platforms in the GoM included the relative percentages of the sensitive species like crustaceans versus other more tolerant species such as polychaetes that are often enhanced by contaminant presence. The government of Nigeria should be commended for its efforts through the UNEP in finding a permanent solution to the oil spill in Ogoniland.

Nomenclature

NH_3 - ammonia
TOC - Total Organic Carbon
DDT - dichlorodiphenyltrichloroethane
GoM - Gulf of Mexico
COD - Chemical Oxygen Demand
BOD – Biological Oxygen Demand.

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Appendices

Glossary
Abyssal/bathyal – found in the very deepest areas of the oceans or on the deep ocean floor.
Benthic – relating to or characteristic of the bottom of a sea, lake, or deep river, or the animals and plants that live there.
Benthos – the animals and plants that live on or in the sediment at the bottom of a sea, lake, or deep river.
Bioturbation – the effects of organisms on the sediment before the sediment hardens into rock.
Foraminifera – large protozoans found mainly in seawater that have shells perforated with many small holes through which temporary cytoplasmic protrusions pseudopodia project.
Infauna – creatures living under sea floor-organisms that live in the tubes or burrows beneath the surface of the sea floor.
Invertebrates – any animal lacking a backbone
Macrofauna – animals that can be seen with the naked eye.
Supernanant – the usually clear liquid left above a precipitate or sediment.