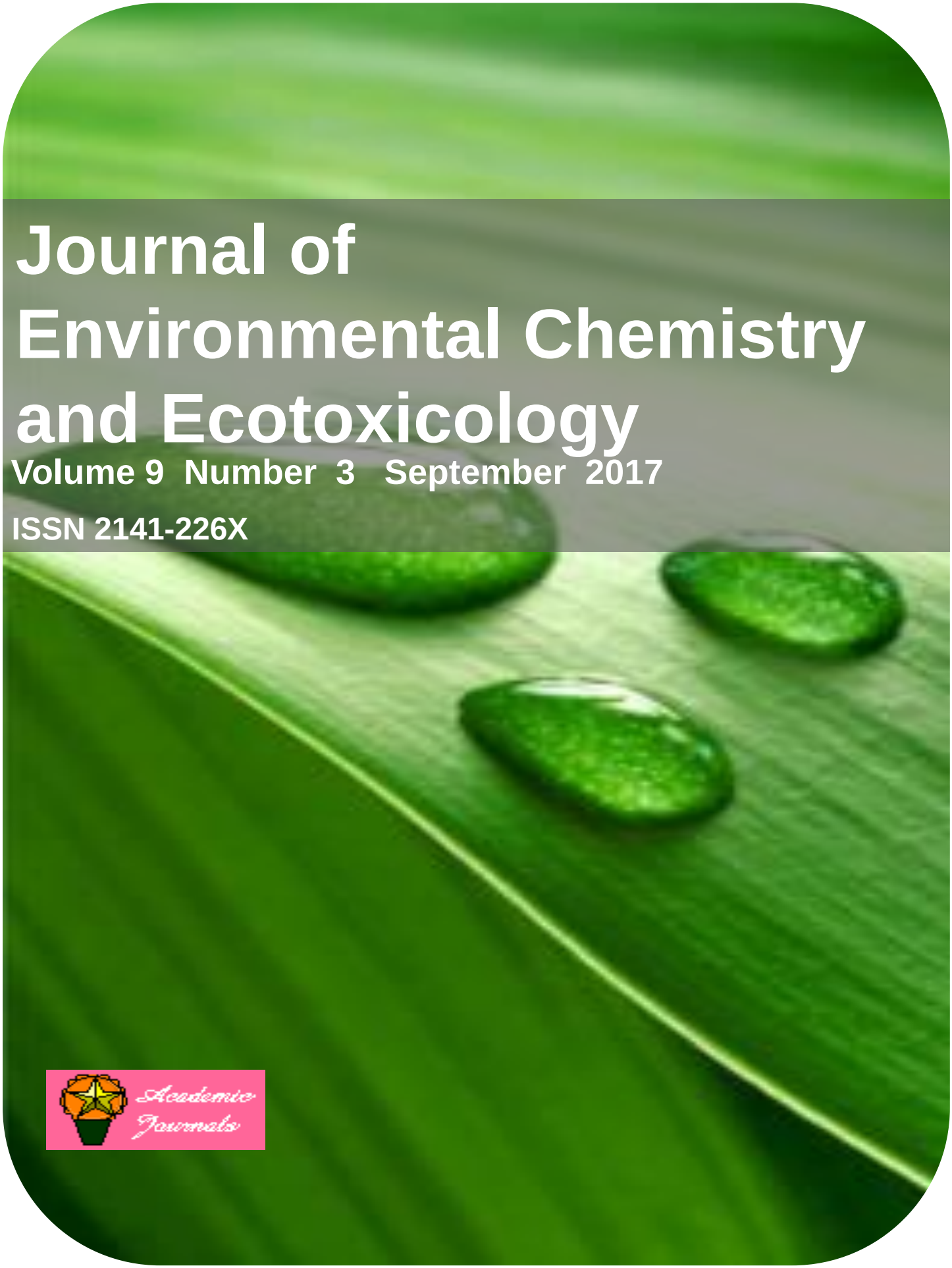

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Full Length Research Paper

Effects of oil and gas exploration and production activities on production and management of seafood in Akwa Ibom State, Nigeria

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The current daily crude oil production in Nigeria stands at about 2.0 million barrels per day thus placing Nigeria as the 6th largest oil producing country in the world. Volumes of petroleum and its production wastes streams find their way into the inland waters and oceans. Seafood is any form of sea life regarded as food by humans including edible sea seaweeds and microalgae widely eaten as seafood, especially in Asia. "Seafood" is extended to fresh water organisms eaten by humans. Effects of petroleum exploration and production (E and P) activities on seafood are enormous and range from poor seafood health to extinction due to non-spawning and death as a result of pollution. Petroleum E and P activities and their influences on production and management of seafood in Nigeria is herein reviewed showing some field observations and research findings justifying the influences. The impacts of petroleum E and P activities on the production and management of seafood in Nigeria is partly due to non-integration of biodiversity and ecosystem services (BES) into petroleum E and P operations and partly due to non-enforcement of existing legal framework as a result of duplicity and overlap of functions of regulatory agencies and lack of political will power.

Key words: Petroleum activities, seafood, environmental pollution, oil spills, regulatory framework.

INTRODUCTION

According to Udotong (1995), petroleum exploration and production (E and P) activities in Nigeria dates back to 1903 when Mineral Survey company began mineralogical studies in Nigeria with the first phase of the drilling activity undertaken by a German Company known as the Nigerian Bitumen Corporation following reports by natives of oil seepages along the Eastern part of Lagos. With the discovery of crude oil, it became the mainstay of the

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Nigerian economy and contributes about 85% of the country's foreign exchange earnings (Udotong and Udotong, 2007). The current daily crude oil production in Nigeria stands at about 2.5 million barrels per day (MBOPD) thus placing Nigeria as the 6th largest oil producing country in the world (Udotong, 2000).

However, greater proportions of the Nigerian crude oil are lost through crude oil theft/bunkering and oil spills, and are either not reported or are grossly under-reported (Udotong and Udotong, 2016).

Generally speaking, seafood is any form of sea life regarded as food by humans. They include all of the fin fishes and shellfishes. Shellfish include various species of mollusks, crustaceans and echinoderms. Historically, sea mammals such as whales and dolphins have been consumed as food, though that happens to a lesser extent these days. Edible sea plants, such as some seaweeds and microalgae are widely eaten as seafood around the world, especially in Asia. In some places, the term "seafood" is extended to fresh water organisms eaten by humans; so all edible aquatic resources are regarded as seafood. For the sake of completeness, this article includes all edible aquatic life.

Seafood is a renewable resource which can provide economic benefits for Nigeria for centuries, if properly managed. Given its availability and relatively cheaper cost, seafood has become the major source of nutrition for the people of Nigeria (Sokari and Udotong, 1998; Udotong and Sokari, 1998), most of who are the rural poor populations that are not economically well off. Seafood remains the main product consumed in terms of animal protein in Nigeria.

As fish is a natural product, nature decides the supply levels. The supply decides the price levels subject to the buying power. When there is excess catch of particular species and the end markets are glutted with that species, the trawlers are under pressure to off-load the fish and return for their refill/production. At that point in time, the prices will be cheaper. At the same time when the season is over or the particular species is in short supply, the prices will be at a premium.

Statement of the problem

In Nigeria and in most developing countries, there is a serious threat of protein energy malnutrition (PEM) and malnourishment (Udotong and Sokari, 1998). Widespread poverty due to global economic recession has led to the increased consumption of some seafood by some residents of coastal communities in Nigeria in particular and the world in general. Seafood is consumed all over the world and provides the world's prime source of high-quality protein. About 14 to 16% of animal proteins are consumed worldwide with over one billion people relying on seafood as their primary source of animal protein (Udotong et al., 2015).

All phases of petroleum E and P activities generate wastes streams that could impact the environment negatively (Udotong and Udotong, 2015), if not properly managed in line with industries best practices. Moreover, increased oil and gas production activities thus results in increased volume of the associated wastes streams and oil spills that find their way into the inland waters and oceans. It is important to mention that the ultimate effects of the oil spills and the E and P waste streams are on the aquatic biodiversity in general, and seafood in particular (Eka and Udotong, 2003).

Seafood is considered a renewable resource which provides economic benefits for Nigeria for centuries, if properly managed. The effects of petroleum E and P waste streams and oil spills, as well as other activities on the aquatic resources in general and seafood in particular are enormous and can not be over-emphasized. They range from poor seafood health through poor quality to extinction due to non-spawning or over-exploitation and death as a result of pollution. The resultant effect is that pollution due to petroleum E and P activities has affected seafood production and management in Nigeria. As a result of this, seafood if found, are much more costly than the conventional protein sources and are therefore not affordable by the rural poor populations who stand the risk of suffering from protein energy mal-nutrition (PEM) (Udotong and Sokari, 1998; Sokari and Udotong, 1998).

What has been done so far?

So far there has been some legal and administrative framework that has been put in place to protect the environment from oil pollution. Table 1 presents a few of the legal provisions for environmental protection from petroleum pollution. Besides, through the "Polluter pay principle", the oil company operators are required to pay compensation for economic crops as well as clean up any oil spill within their prospects, weather it is spilled by them or not. The Oil Producers Trade Section (OPTS) of the Nigerian National Petroleum Company (NNPC) sets rates for compensation payments for economic crops but not for seafood in Nigeria.

Aims and objectives of this review

The overall objective of this review is to highlight the impacts of the huge petroleum E and P activities in the Niger Delta, Nigeria in general and Akwa Ibom State in particular on the production and management of seafood in Nigeria. The specific aims of this review are to:

i. Justify Akwa Ibom State, Nigeria as the "Seafood Basket" of Nigeria;
ii. Review the magnitude of petroleum E and P activities in Nigeria, in general and Akwa Ibom State in particular;

Table 1. Legal provisions for environmental protection from petroleum pollution in Nigeria.

S/N	Legal provisions for environmental protection from petroleum pollution
1	Act No. 9 of 1 June 1965: Hydrocarbon Oil refineries Act; Cap.339 LFN 1990
2	Act No. 28 of 13 July 1967: Petroleum Control Act; Cap. 351 LFN 1990
3	Act No. 34 of 22 April 1968: Oil In Navigable Water Act; Cap. 337 LFN 1990
4	Act No. 31 of 10 June 1971: Sea Fisheries Act; Cap. 404 LFN 1990
5	Act No. 25 of 4 June 1973: Petroleum Technology Development Fund Act; Cap. 355 LFN 1990
6	Act No. 35 of 7 November 1975: Petroleum Production and Distribution (Anti-Sabotage) Act; Cap. 353 LFN 1990
7	Act No. 31 of 4 October 1956: Oil Pipelines Act; Cap. 338 LFN 1990
8	The Petroleum Act of 1969
9	Act No. 24 of 1965: Oil Pipelines Act (Amendment).
10	Regulations of 13 July 1967: Petroleum Regulations.
11	Regulations of 22 April 1968: Oil in Navigable Waters Regulations (Issued by Legal Notice 101 of 1968).
12	Decree No. 51 of 14 November 1969: Petroleum Drilling and Production Decree.
13	Regulations of 27 November 1969: (Drilling and Production) Regulations 1969 (Regulation 25).
14	Act No. 25 of 4 June 1973: Petroleum (Drilling and Production) (Amendment).
15	Act No. 38 of 26 August 1971: Territorial Waters (Amendment) Act.

Figure 1. Some parts of the Akwa Ibom State Coastline of about 120 km.

iii. Highlight the potential and associated effects of each of the activities of each phase of petroleum production on seafood in Nigeria;
iv. Review existing regulatory (legal and administrative) framework for petroleum resources management and seafood production and management in the country;
v. Document current/on-going production statistics and management of seafood in Nigeria in general and Akwa Ibom State in particular; and
vi. Proffer a way forward towards the conservation and utilization of seafood while sustainably exploiting the petroleum resources.

AKWA IBOM STATE AS THE SEAFOOD BASKET OF NIGERIA

General

Nigeria has an extensive coastline of approximately 900 km and an Exclusive Economic Zone (EEZ) of about 217,313 km² (Sea Around Us, 2007). Out of this, Akwa Ibom State has a coastline of about 120 km (Figure 1), the longest coastline in Nigeria, extending from Eastern Obolo Local Government Area (LGA) through Ibeno LGA to Mbo and Oron LGAs. Out of the 31 LGAs in Akwa Ibom State,

Figure 2. Artisanal fishing at the background along the Akwa Ibom State coastline.

about half of them are considered coastal LGAs (Udotong et al., 1997). Thus, Akwa Ibom State is truly one of the maritime States in Nigeria. The Petroleum Industry located in Akwa Ibom State (Mobil Producing Nigeria Unlimited; MPNU, a subsidiary of Exxon Mobil Corporation) has its oil wells off the Akwa Ibom State continental shelf.

Much of the State's population and economic activities are located along the coast. According to the 1991 National Population Commission (NPC, 1991) census figures, approximately 0.68 million people (about 49% of Akwa Ibom State population) inhabit the coastal area. The socio-economic activities in the coastal areas of Akwa Ibom State include petroleum drilling, fishing, transportation, tourism, etc with fishing being the most prominent (Figure 2).

Fisheries resources of Akwa Ibom State

According to Udotong et al. (1997), Akwa Ibom State has a diversity of fin and shell fishes of about 199 species, belonging to about 78 families in the brackish and marine environments. Tables 2 and 3 present the fish assemblages and indices of preponderance in Akwa Ibom State coastal waters.

Among the species identified, only relatively few are of real economic importance as artisanal fisheries resources. These include demersal stocks such as croakers (*Pseudotolithus* spp), the bigrid catfish (*Chrysichthys nigrodigitatus*), shinynose (*Polydactylus quadrifilis*), the pelagic clupeids *Ethmalosa fimbriata* and longfinned fishes.

The index of preponderance (IP) indicates the degree of effective contribution of each species to the overall catch in a given study location. Index of preponderance is a weighted assessment involving both number and biomass of the fish caught.

The indices of preponderance indicate that *Pseudotolithus elongates*, *E. fimbriata, Liza grandisquamis, L. falcipinnis, Ilisha africana, C. nigrodigitatus and C. auratus* were the most dominant and abundant of all the species examined particularly in the dry season (Table 3).

The fisheries resources of the brackish and marine waters in the State can be classified into five (5) major groups as follows:

a) Inshore pelagic fishery: Bonga fish (*Ethmalosa fambriata*), West African Herring (*Sardinella maderensis*) and West African shark (*Hisha africana*) are the target fishes of inshore pelagic fishery. Bonga fish is the most valuable and abundant fish in the artisanal fisheries sector. An estimated annual mean sustainable yield (MSY) of the resources in the estuaries and littoral zone is about 8,200 tons (Udotong et al., 1997).

b) Offshore pelagic fishery: Tuna and tuna-like fishes such as skipjack *(Katsuwonus pelamis),* yellow fin *(Thunnus albacares)* and brgeye (*Thunnus obesus*) are the targets of the state's offshore pelagic fishery. The tuna-like species identified within the state's coastal zone include *Sarda sarda, Elagatis pinnulata and*

Table 2. Fish species assemblage in water bodies in Akwa Ibom State.

Taxonomic Unit Family/Species	Magnitude of abundance	
	Dry season	Wet season
Cichlide		
Tilapia guineensis	++	+
Bagridae (claroteidae)		
Chrysichthys nigrodigitatus	+++	+++
Chrysichthys auratus	+	+++
Dasyatidae		
Dasyatis margarita	+	-
Ariidae		
Arius heudeloti	++	+
Bothidae		
Citharichthys stampflii	+	+
Cynoglossidae		
Cynoglossus browni	-	-
cynoglossus senegalensis	+	+
Clupeidae		
Ethmalosa fimbriata	+++	-
Llisha africana	+++	+
Pellonula leonensis	++	-
Sardinella madarensis	+	-
Sardinella sp	+	-
Hemirhamphidae		
Hemithamphus brasiliensis		+
Carangidae		
Hemicaranx bicolor	+	+
Trichonotus teraia	+	-
Caranx senegalus	++	+
Selene dosalis	+	+
Chloroscombrus chrysurus	+++	+
Drepanidae		
Drepane Africana	+	+
Ephippidae		
Drepane africana	+	++
Eleotridae		
Bostriychus africanus	++	-
Eleotris vittata	+	-
Trichiuridae		
Trichiurus lepturus	+	+
Monodactilidae		
Psettias sebae	+	-
Mugilidae		
Liza grandisquamis	+++	++
Liza falcipinnis	+++	++
Mugil cephalus	++	+
Polynemidae		
Galeoides decadactylus	++	+
Polydactylus quadrifilis	++	-
Sphyraenidae		
Sphyraea sphyraena	+	-
Gobiidae		

Table 2. Contd.

Porogobius schlegeli	+	+
Periophthalmus barbarus	+++	++
Sciaenidae		
Pseudotolithus elongates	+++	++
Pseudotolithus senegalensis	+++	++
Pseudotolithus typus	++	+
Pteroscion peli	+	-
Haemulidae		
Pomadasys jubelini	+	-
Brachydeuterus auritus	+++	-
Lutjanidae		
Lutjanus agennes	+	-
Lutjanus goreensis	+	-
Total No. of families	**21**	
Total No. of species	**42**	

Source: EIA Report of Qua Iboe Field Development Project (2005).

Table 3. Indices of preponderance (IP) indicating the dominant species in the catches from water bodies in Qua Iboe Field Development project area.

Taxonomic Unit	Index of preponderance	
	Dry season	Wet season
Chysichthys nigrodigitatus	5.40	10.42
Chrysichthys auratus	1.49	6.56
Ethmalosa fimbriata	15.87	-
Dasyatis margarita	0.15	-
Drepane africana	0.24	0.13
Llisha africana	8.98	1.92
Liza grandisquamis	6.88	3.30
Liza falcipinnis	3.50	2.72
Pseudotolithus elongates	12.89	4.85
Polydactylus quadrifilis	0.28	-
Periophthalmus barbarus	0.36	0.78

Source: EIA Report of Qua Iboe Field Development Project (2005).

Euthynnus alleteratus. Figures 3 to 6 show some fish landings from inshore pelagic fishery in some fishing ports in Akwa Ibom State found within the Exclusive Economic Zone (EEZ) of Akwa Ibom State with the annual yield estimated at 2,100 tons (FDF, 2008).

c) Inshore demersal fishery: The targets of the inshore demersal fishery in the State are the croaker fauna of silver to grey fish, the thread fin, the arid catfish, soled and spade fish. The annual MSY of 5,000 tons has been estimated for the inshore trawl fishery (Akwa Ibom State Ministry of Agriculture and Natural Resources, Fisheries Department, Personal Communications).

d) Offshore demersal fishery: The target fish families of the offshore demersal fishery include Sparidae, Ariomidae and Priacanthidae. An estimate annual potential yield of the offshoredemersal fish resources in Akwa Ibom State waters is put at about 1,630 tons (Akwa Ibom State Ministry of Agriculture and Natural Resources, Fisheries Department, Personal Communications).

e) Shellfishes: The shell fish resources include shrimps, crabs, lobsters and mollusks. The coastal water supports a very rich organic matter brought down by the various rivers (Qua Iboe, Imo and Cross Rivers) (Udotong and Udotong, 2015). Shrimps are found in abundance offshore of the mouth of these three estuaries with about 3,000 tons of shrimps caught annually from our coastal waters (Akwa Ibom State Ministry of Agriculture and Natural Resources, Fisheries Department, Personal Communications). Among the important species that dominate the coastal waters of the State include the pink shrimps (P*enaeus notialis*) and the Guinea shrimps (*Parapenaeopsis atlantica*). Other species are also found within the State coastal water.

Figure 3. A typical fish landing at Inshore Pelagic Fishery in the State.

Figure 4. "Traditional" weight determination at Inshore Pelagic Fishery in the State.

Figure 5. *Ckymbium glans*, a marine snail.

Figure 6. Fishermen's boats at Upenekang set to sail out for fishing.

Figure 7. Map of the Niger Delta region.

Mollusks such as bivalves are highly exploited by the adult female and youth coastal dwellers. The mangrove oysters (*Crassostrea gasar*) and whelk (*Thias callifera)* occur abundantly in the coastal swamps and estuaries where they are exploited at subsistence level. Other bivalves harvested include the clams, *Senilia senilis, Anadara senegalensis* and bloody cockles, *Cardium costatum.* Other mollusks like periwinkle, *Tympanotonus fuscatus* and *Cymbium glans* (Figure 5) are also harvested abundantly.

Seafood industry in Akwa Ibom State

The Seafood industry in Akwa Ibom State consists of three major sectors; artisanal, industrial and aquaculture.

(a) Artisanal fishing: The artisanal fishing in Akwa Ibom State consists of small sub-sectors such as estuarine and inshore canoe fisheries. The sector operates small open crafts which may or may not be motorized with fishing gears ranging from hooks, traps to drag and gill nets. This sector is characterized by low capital outlay, low operational costs, low technology application but labour intensive. In spite of these disadvantages, the artisanal fisheries sector remains the backbone of fish production and contributes over 90% of annual fish production in the State (Udotong et al., 1997).

(b) Aquaculture: In Akwa Ibom State, aquaculture is practiced at subsistent level and contributes to about 0.5% of fish production in the State. This low contribution is due to the acidic nature and soil characteristics of the mangrove swamps which have not rendered this vast area very productive for aquaculture. These problems have resulted in low yield and mass mortality.

Aquaculture in Akwa Ibom State is carried out mainly in small tidal earthen ponds constructed in swamps or close to an existing body of water although there are a few concrete ponds in the hinterland. Tilapia and catfish are the major species farmed by local fish farmers.

The fish culture system in the State ranges from extensive to semi-intensive through polyculture of *Tilapia* sp in combination with *Clarias, Heterobranchus* sp or *Mugil* sp. Aquaculture has gained importance in the last few years in the International Fund for Agricultural Development (IFAD) facility in the State and has great potentials in the Fisheries Sector of the State's economy.

(c) Industrial fisheries: The industrial sector of the Akwa Ibom State Fisheries is the least developed because it is characterized by high capital outlay on marine vessels, cold storage facilities and advanced technology (fish finder, rader, navigation and communication equipment). While the artisanal fishery sector concentrates on local markets, the industrial fishery sector targets both local and foreign markets. One major attribute of the industrial fishery sector in the State is its domination by foreigners (Ghanaians, Togolese, etc) (Figure 6) and its generation of foreign exchange through the exports of shrimps. The Ebughu and Uta Ewa fishing terminals are the most prominent in the industrial fishery sector within the Akwa Ibom State coastal zone.

PETROLEUM EXPLORATION AND PRODUCTION (E AND P) ACTIVITIES AND EFFECTS ON SEAFOOD PRODUCTION AND MANAGEMENT

Petroleum production in the Niger Delta and Akwa Ibom State

The Niger Delta Region (Figure 7) initially comprised the six States, viz; Akwa Ibom, Bayelsa, Cross River, Delta,

Figure 8. Nigeria's oil production between June 2016 and April 2017. Source: (Trading Economics, 2017 2017).

Edo and Rivers. However, it was later redefined to include the contiguous three other oil-producing States of Abia, Imo and Ondo (NNPC, 2005), with Bayelsa and Delta States at the centre of the Niger Delta Region.

The Niger Delta is situated in the gulf of Guinea and extends throughout the Niger Delta province as defined by Klett et al. (1997). The Niger Delta Region is among the largest wetlands in the world (NNPC, 2005). The region covers an area of 700,000 km^2, with sandy coastal ridge barriers, brackish or saline mangroves, permanent and seasonal swamp forests, as well as low land rain forests with the entire area criss-crossed by a large number of rivers, rivulets, streams, canals and creeks (NNPC, 2005).

The Niger Delta is endowed with immense natural resources, especially hydrocarbon deposits. Crude oil production and export from the region, in the range of two million barrels a day, dominates the Nigerian economy, accounting for over 90% of the Nation's total export earnings (Trading Economics, 2017).

Crude oil production in Nigeria increased to 1,663,000 BOPD in June, 2017 from 1,494,000 BOPD in May, 2017. Crude oil production in Nigeria averaged 1892,300 BOPD from 1973 until 2017, reaching an all-time increase of 2,475,000 BOPD in November, 2005 and a low record of 675 BOPD in February, 1983. Nigeria is estimated to have proven oil reserve of 37.2 billion barrels and natural gas reserve of 180 trillion cubic feet, the 7th largest in the world (https://tradingeconomics.com/nigeria/crude-oil-production, 11th Aug 2017) (Figure 8).

Akwa Ibom State (Figure 9) is one of the thirty-six States in the Federal Republic of Nigeria with a population of over 3.5 million people (Mbat et al., 2013). It was created on 23rd September, 1987, and has 31 Local Governments including Uyo, the State Capital.

Akwa Ibom State is located at the south-eastern corner of Nigeria, between latitudes 4° 30' and 5° 33' North and longitudes 7° 30' and 8° 25' East. The State is rich in mineral resources, particularly petroleum hydrocarbon deposits. Akwa Ibom State as the highest oil producing state in Nigeria recorded 504,000 barrel per day, which is 31.4% of the total oil produced in Nigeria per day (Oil Revenue, 2017).

The Akwa Ibom State Coastal Zone (AKSCZ) is richly endowed with a variety of minerals (Figure 10). The most important mineral presently exploited is crude oil and its associated gas. The coastal zone is an area where prolific oil and gas discoveries have been made. While Nigeria's current oil resources are estimated at 21 billion barrels and its gas reserves are approximately 11 trillion cubic feet (Oil Revenue, 2017), it is worthy of note that the significant increase in crude oil and gas resources since 2012 is related to discoveries in the deep offshore zone of Akwa Ibom State.

In February 1985, after 15 years of production, Mobil Producing Nigeria Unlimited (MPNU) hit the one billion barrel production mark. Ten years later, specifically in May, 1995, they attained the two billion barrel production mark (Udotong et al., 1997). Today, Akwa Ibom State is the largest producer of crude oil in Nigeria with the highest financial allocation on the basis of the current 13% Federal Government of Nigeria's Revenue allocation formula (Oil Revenue, 2017).

Petroleum E and P phases and effects on seafood production

Several studies indicate that all phases of petroleum E and P activities generate wastes streams that could impact the environment negatively, if not properly managed in line with industries best practices (Udotong, 1995; Udotong et al., 1997; Ekop and Udotong, 2004) whether it is offshore (Figure 11), onshore (Figure 12) or in inland water. Table 4 presents the different phases of petroleum E and P activities and the likely impacts on seafood during the upstream and downstream petroleum E and P activities.

In downstream operations of the petroleum production

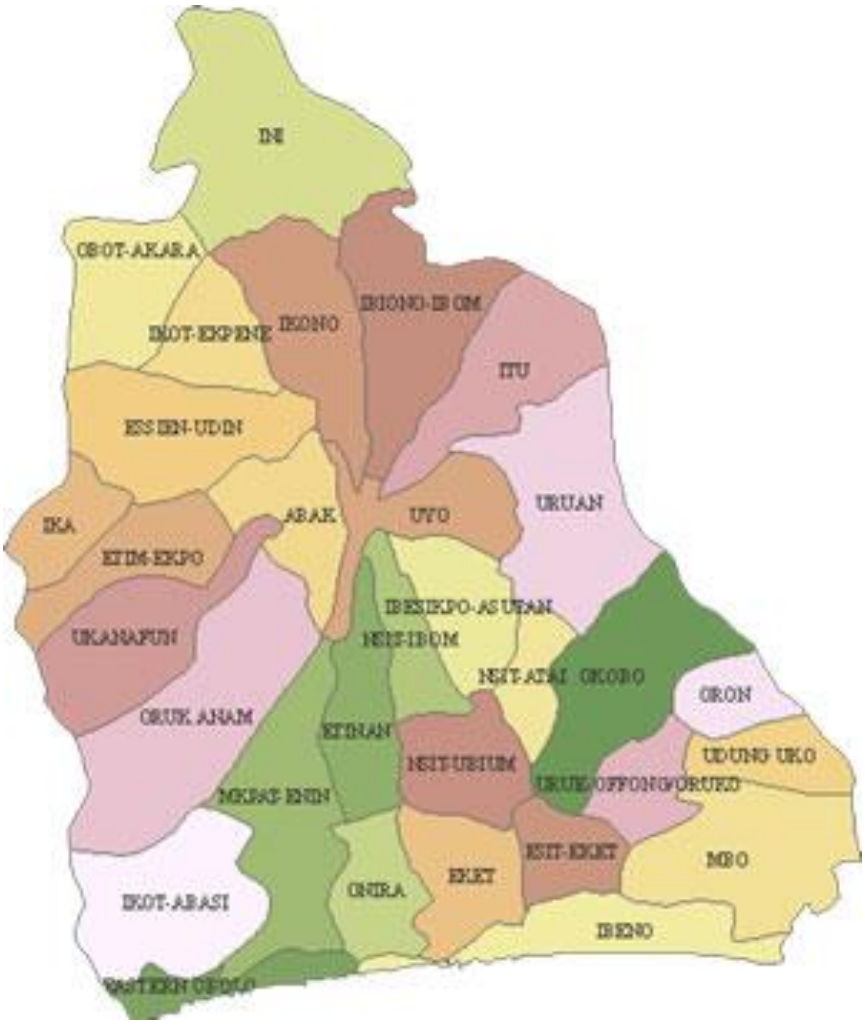

Figure 9. Map of Akwa Ibom State showing Local Government Areas.

activities, oil terminals, tank farms (Figure 14), depots, pipelines, tankers, trucks, filling stations, and so on spill oil into the environment which ultimately end up in water bodies with its adverse impacts on seafood (Eka and Udotong, 2003).

Origin of influence of petroleum E and P activities on seafood in Akwa Ibom State

The implication of Akwa Ibom State being the highest producer of petroleum in Nigeria is that it is therefore the State that is most impacted by petroleum E and P activities. It has been known that all phases of petroleum E and P activities generate wastes streams that could impact the environment negatively, if not properly managed (Udotong, 2000). This is true of the State in terms of the influence of petroleum E and P activities on the production and management of seafood resources.

Although the influence of petroleum E and P activities on the production and management of seafood resources may have existed unnoticed since the origin of oil activities in 1903 when crude oil exploration started in Nigeria, its obvious manifestation may have been very recent. In Akwa Ibom State particularly and Nigeria in general, it became obvious when the first major oil spill disaster occurred from Idoho Platform of Mobil Producing Nigeria Unlimited on 12 January, 1998. The spill traversed the entire Atlantic Ocean shoreline up to Lagos lagoon. Figures 17 and 18 show some oil spill scenes in the Niger Delta region, Nigeria. When this happened, seafood resources in the country were adversely affected and the spiral effects on socio-economic activities of the country cannot be over-emphasized.

Other sources of crude oil into the environment

One common but incorrect perception of the petroleum exploration and production industry is that, it is responsible for large-scale hydrocarbon contamination of

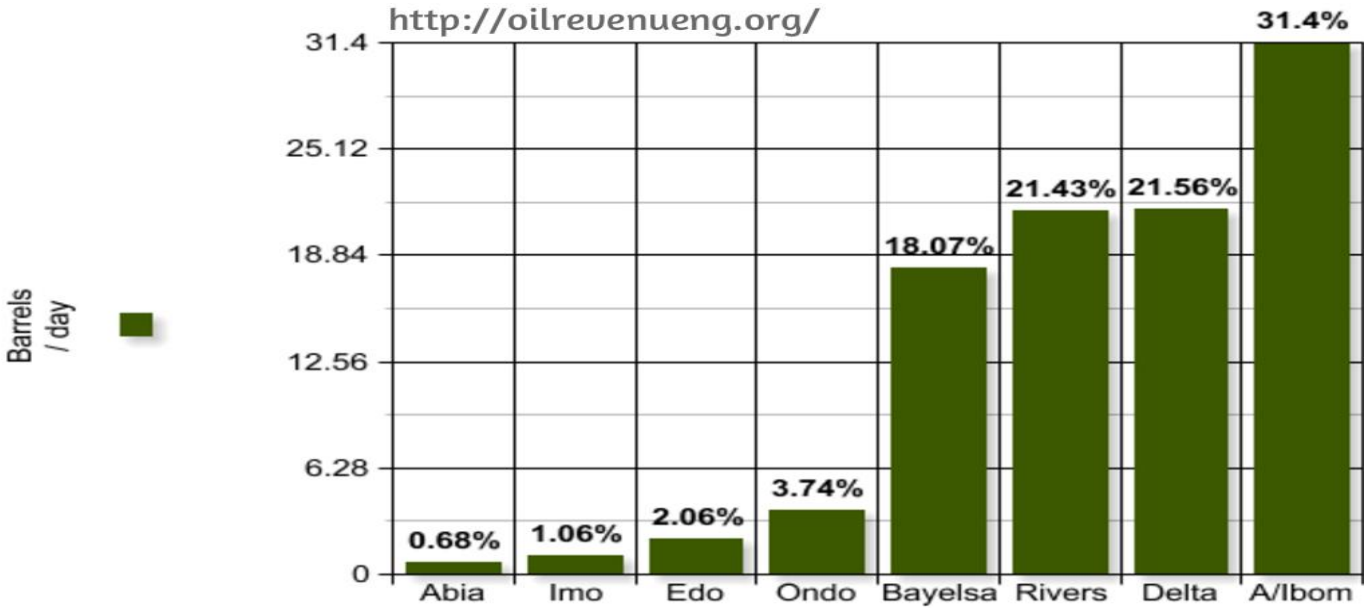

Figure 10. Niger Delta States and percentage of National crude oil production. Source: Oil Revenue (2017).

Figure 11. Offshore production platform.

Figure 12. Onshore oil well.

Table 4. Different phases of petroleum E and P activities that could impact seafood.

S/N	Petroleum E and P phases	Petroleum E and P activities and likely impacts on seafood
		Upstream activities
1	Exploration	Seismic operations: Detonation of explosives / misfires (onshore) or waves from shotgun (offshore) will cause fishes to be scared and move away temporarily; wastes from Base camps / House Boats (Figure 13) will pollute water bodies resulting in seafood mortality and tainting.
2	Appraisal and development drilling	Oil well Drilling: Wastes from Base camps; Drilling wastes discharges; Oil spills; gas flares; and so on will pollute water bodies resulting in seafood mortality and tainting.
3	Production / Operations	Drilling wastes and produced water discharges; Oil spills; gas flares; pipeline laying; Pipeline bursts, whether buried (Figure 15) or above ground (Figure 16) discharge of hydrotest water; and so on will pollute water bodies resulting in seafood mortality and tainting.
4	Abandonment / Decommissioning	Residual oil in pipes and well bore, residual chemicals in containers, and so on will pollute water bodies resulting in seafood mortality and tainting.
		Downstream activities
1	Transportation	Pipeline laying; pipeline burst; Oil spills; discharge of oily sludge and other wastes streams and hydrotest water; ballast water discharges; and so on will pollute water bodies resulting in seafood mortality and tainting.
2	Marketing	Tanker accidents, oil spills during tanker loading; and so on will pollute water bodies resulting in seafood mortality and tainting.
3	Refining / Petrochemicals	Discharge of wastes water from petrochemical / refinery, oil leaks, release of other chemicals into the environment, and so on will pollute water bodies resulting in seafood mortality and tainting.

Figure 13. Wastes generated from base camps like this house boat affect seafood.

Figure 14. A typical petroleum tank farm / terminal that can experience oil spill.

the sea. The total amount of hydrocarbons that enter the sea is estimated to be 3.2 million metric tons per year (National Research Council (NRC), 1985). The individual contributions from the different sources of hydrocarbons are given in Table 5 (Udotong and Udotong, 2015).

From Table 5, the primary source of hydrocarbon released into the ocean is from transportation by tankers. Oil production from offshore platforms contributes about

Figure 15. Buried oil pipelines.

Figure 16. Above ground oil pipelines.

Figure 17. Oil spill on shoreline.

Figure 18. Remote aviation fuel spill scene after 12 years.

Table 5. Sources of hydrocarbon inputs into the sea.

Source	Amount introduced (metric tons/year)
Natural Source	**0.25**
Marine seeps	(0.2)
Sediment erosion	(0.05)
Offshore Production	**0.05**
Transportation	1.47
Tanker operations	(0.7)
Dry-docking	(0.03)
Marine terminals	(0.02)
Bilge and fuel oils	(0.3)
Tanker accidents	(0.4)
Non-tanker accidents	(0.02)
Atmospheric Transport	0.3
Municipal and Industrial	1.18
Municipal wastes	(0.7)
Refineries	(0.1)
Non-refining industrial wastes	(0.2)
Urban runoff	(0.12)
River runoff	(0.04)
Ocean dumping	(0.04)
Total	**3.2**

Source: National Research Council (1985).

1.56% of the total amount of oil entering the sea.

Oil spill data in Nigeria up to 2013

Oil spills occur frequently in the Niger Delta (Eka and Udotong, 2003), sometimes more than once or twice in a day. Available oil spill data in Nigeria was from 1976 till 1996 only. Table 6 presents the most recent oil spill statistics in Nigeria, from 1976 to 2013, for the first time.

Effects of Petroleum E and P activities on fisheries resources

a) Effects on artisanal seafood production in the wild

The most obvious effect of petroleum E and P activities on seafood resources is the release of waste streams or oil spill into water bodies resulting in the mortality of the fish larvae and juveniles and even the adult fishes and other seafood. The effect of this can last long since the larvae and juveniles will be the most vulnerable. This will lead to the fishermen hanging their nets partly because of fear of loosing their nets or any other fishing gears due to oil stains and partly because of fear of low/poor catches (Figure 19).

Moreover, consumer safety and concerns about consumption of seafood from polluted environment as well as regulatory control will limit fishing activities during oil spills. The spiral effects of this loss of source of livelihood on socio-economic activities of the residents can be quite frustrating and devastating.

Upton (2011) in a report to members of Congress (Congressional Research Service, CRS, 2011), summarized the effects of the Deepwater Horizon Oil Spill and the Gulf of Mexico Fishing Industry as follows:

"*On April 20, 2010, the Deepwater Horizon oil drilling rig was destroyed by explosion and fire, and the oil well began releasing oil into the Gulf of Mexico. The oil spill caused significant economic harm to the Gulf Fishing Industry because of fishery closures and consumer concerns related to the safety of Gulf seafood. Intermediate and long-term concerns are related to impacts on marine populations and degradation of fisheries habitat necessary for spawning, development of early life stages, and growth.*

The closing and opening of fishing grounds has involved a tradeoff between ensuring public safety and providing fishing opportunities to recreational and commercial fishermen. In addition to public health concerns, uncertainties related to Gulf seafood safety could further compromise the reputation of Gulf seafood …"

b) Effects on aquaculture

Each time oil spills and floods a constructed fish pond,

Table 6. Oil spill statistics in Nigeria (1976 to 2013).

SN	Year of spill	No of spill incidents	Total volume of spill
1	1976	128	26.157
2	1977	104	32.879
3	1978	154	489.294
4	1979	157	694.117
5	1980	241	600.511
6	1981	238	42.722
7	1982	257	42.841
8	1983	173	48351.30
9	1984	151	40209.00
10	1985	187	11876.60
11	1986	155	12905.00
12	1987	129	31866.00
13	1988	208	9172.00
14	1989	195	7628.16
15	1990	160	14940.82
16	1991	201	106827.98
17	1992	378	51187.96
18	1993	428	9752.22
19	1994	515	30282.67
20	1995	417	63677.17
21	1996	435	46353.12
22	1997	339	81727.85
23	1998	399	99885.35
24	1999	225	16903.96
25	2000	637	84071.91
26	2001	412	120976.16
27	2002	446	241617.55
28	2003	609	35284.43
29	2004	543	17104.00
30	2005	496	10734.59
31	2006	461	13772.92
32	2007	482	10848.00
33	2008	740	49524.80
34	2009	849	48935.56
35	2010	582	25383.15
36	2011	676	66907.87
37	2012	841	17665.03
38	2013	883	3.749.21

Source: Udotong (2017).

the result is usually quite devastating and almost irreparable. This is because the fishes will all die and oil stains on the banks of the fish pond will be difficult to dislodge in a hurry. The effect is usually a colossal loss.

c) Effects of oil spill on seafood health and quality

Oil spills are known to result in mortality of seafood, eggs, and early life stages challenges, harm to habitat and other elements of the ecosystem. It also causes fish tainting to any surviving seafood as well as bioaccumulation of some toxic chemical substances that could reach toxic thresholds. Regulatory agencies monitor the fish and ecosystem quality at spill sites and decide when to close and open such sites to fishing as a precautionary measure to ensure the safety of seafood. During the closures, most fishermen hang their fishing gears (Figure 19) while a few others continue; however, but fish landings and associated revenues decrease significantly. During this closure, the demand for seafood

Figure 19. Fishermen hanging their nets due to oil spill at Upenekang Beach.

decrease because of changes in consumer perceptions and safety issues related to the spill.

It is important to mention that in spite of the major oil spill disasters that have occurred in Nigeria in the past (Table 6), there has been no single case of polluted site closure for fishing activities. This may be partly due to inadequate legal and administrative framework and partly due to the lack of political will power for enforcement of existing regulations. Tables 7 and 8 present the physicochemical characteristics of water samples from Akwa Ibom State coastal waters.

The result of heavy metals in sediment samples was taken during the Addendum EIA study. Values of heavy metals in the sediment samples were within limits reported for other natural unperturbed ecosystems in the Niger Delta region (RPI/NNPC, 1985). Nutrient levels were high indicating that the sediments probably served as sink. The sediment characteristics reflected a healthy productive natural aquatic ecosystem.

MANAGEMENT OF SEAFOOD IN NIGERIA

General

Before the advent of oil boom, Nigeria was not only self-sufficient in agricultural produce but exported some agricultural commodities like groundnuts, palm oil, and so on. With the discovery of crude oil, agricultural activities including our seafood industry suffered; agricultural productivity including fisheries production declined to the extent that importation of agricultural products like rice and seafood into Nigeria was encouraged through fiscal means. Some issues confronting the management of seafood in Nigeria are:

1) Environmental change - climatic patterns and anthropogenic activities like petroleum E and P and other industrial activities;
2) Exogenous factors - human population, lack of infrastructure like constant electricity supply, poverty and food demand; and
3) Inadequate legal framework and lack of political will power for enforcement of existing regulations.

Legal and administrative framework for seafood production and management in Nigeria

The Federal Fisheries Unit of the Federal Ministry of Agriculture and Natural Resources (Nigeria's Department of Agriculture) regulates Seafood imports. The Federal Fisheries Unit issues import license to local firms applying to import after due certifications. The Nigerian Customs Service is the government agency for import duty collection.

According to Adebolu (1978), the present Fisheries laws and regulations of Nigeria mainly deal with the development, management, exploitation and conservation

Table 7. Physicochemical characteristics of water samples from Akwa Ibom coastal waters.

Physio-chemical parameters	Estuarine water		T-Ratio	Offshore water	DPR/FMEnV Limit
	Dry season	Wet season			
	Mean ± SD	Mean ± SD		Mean ± SD	
pH	6.75 ± 0.08	7.34 ± 0.29	3.89*	7.48 ± 0.90	6.0- 9.0
Colour (pcu)	-	-		20.7 ± 1.25	6.5- 8.5
Conductivity (μScm^{-1})	673.53 ± 68.4	229.60 ± 23.4	12.65*	5289.60 ± 49.70	-
Dissolved Oxygen ($mgdm^{-3}$)	6.02 ± 1.38	8.54 ± 0.52	4.29*	8.18 ± 0.36	4.0
Biochemical Oxygen Demand ($mgdm^{-3}$)	3.24 ± 0.78	3.96 ± 0.33	0.87*	4.23 ± 1.72	-
Alkalinity ($mgdm^{-3}$ $CaCO_3$)	43.81 ± 5.01	29.80 ± 2.74	10.79***	37.34 ± 10.6	20-200
Total suspended solids ($mgdm^{-3}$) (TSS)	290.33 ± 4.28	322.70 ± 11.65	7.89**	385.56 ± 25.70	-
Total Dissolved solids ($mgdm^{-3}$)	335.9 ± 3.43	83.45 ± 1.83	20.53***	865.29 ± 63.4	1500
Transparency (cm)	46.10 ± 2.73	31. 55 ± 0.92	6.98**	-	-
Nitrate – Nitrogen (μgdm^{-3})	121.85 ± 10.08	156.92 ± 12.54	14.68***	219.0 ± 76.0	20.00- 50.00
PO_4 – P (μgdm^{-3})	49.92 ± 3.95	29.88 ± 1.20	13.92***	98.42 ± 34.7	5.00
NH_4^+(μgdm^{-3})	0.31 ± 0.23	0.12 ± 0.06	1.24	0.62 ± 0.14	0.50*
NO_2- (μgdm^{-3})	9.27 ± 0.87	7.66 ± 0.12	5.72*	12.17 ± 4.56	-
THC ($mgdm^{-3}$)	0.82 ± 0.58	2.53 ± 0.26	6.56**	2.23 ± 0.27	10.00
SO_4^{2-} ($mgdm^{-3}$)	125.52 ± 0.58	63.29 ± 1.54	18.73***	120.64 ± 15.90	150*
Silicate ($mgdm^{-3}$)	4.10 ± 0.58	1.16 ± 0.43	8.24	4.26 ± 0.48	3.70
Free CO_2 ($mgdm^{-3}$)	2.87 ± 1.27	1.34 ± 0.21	5.66*	3.28 ± 0.65	-
Salinity ($^0/_{00}$)	3.68 ± 0.69	1.07 ± 0.25	9.43***	-	-
Total hardness ($mgdm^{-3}$)				282.6 ± 62.6	
Do saturation (%)				105.00	

* Reference standards in mgl^{-1} unless otherwise stated; Level of significance: * $p < 0.05$; $p < 0.001$; *** $p < 0.001$. DPR = Department of Petroleum Resources; FMEnv. = Federal Ministry of Environment. Source: EIA Report of Qua Iboe. Field Development Project (2005).

Table 8. Heavy metal concentrations in estuarine water samples from Akwa Ibom State.

Heavy metals	Qua Iboe River Estuary		Douglass Creek		WHO Max Permissible	DPR / FMEnv
	Wet Season	Dry Season	Wet Season	Dry Season	Limits	Limits
Cadmium (Cd) ($mgdm^{-3}$)	ND	0.041	0.07	0.058	0.005	<1.0
Cobalt (CO) ($mgdm^{-3}$)	ND	0.271	0.08	0.264	-	-
Zinc (Zn) ($mgdm^{-3}$)	2.14	1.272	3.24	5.051	15.0	<1.0
Copper (Cu) ($mgdm^{-3}$)	0.08	0.064	0.06	0.080	1.5	<1.0
Aluminium (Al) "	3.755	11.45	5.75	12.80	-	-
Nickel (Ni) "	0.237	0.330	0.37	0.685	-	-
Lead (Pb)	ND	0.025	ND	0.047	0.05	<1.0
Manganese (Mn) (μgdm^{-3})	3.2	16.57	6.53	13.70	0.5	5.0
Iron (Fe) ($mgdm^{-3}$)	41.29	59.37	31.29	48.80	1.0	20.0

ND= Not detected; DPR= Department of Petroleum Resources; FMEnv = Federal Ministry of Environ. Source: EIA Report of Qua Iboe Field Development Project (2005).

of the living resources of Nigerian Marine waters. To a very large extent, no effective laws exist to govern the management and conservation of the fisheries resources of Nigeria's inland waters. The few existing ones are not adequately enforced. Some of the existing laws and regulations are presented in Table 9.

The licensing and the fishing regulations are supplements to the Sea Fisheries Act. Fish Production in Nigeria is mainly from the inland waters including Lake Chad. The amount of fish produced annually from the marine waters is about 21.25% (FDF, 2008) and yet all the Fisheries laws and regulations operating in Nigeria are on marine waters.

Nigeria has no specific legislation on aquaculture at national level, nor is this activity mentioned in the Sea Fisheries Decree and Regulations of 1992 and 1971,

Table 9. Legal and Administrative framework for seafood production and management in Nigeria.

S/N	Legal provisions
1	The Sea Fisheries Decree (Act) of 1971; 1992
2	The Sea Licensing Regulations of 1971
3	The Sea Fisheries (Fishing) regulation of 1972
4	The Hxc1usiv Economic Zone Decree (Act) of 1978
5	Inland Fisheries Decree (Act) 1992
6	Oil in navigable waters Decree (Act) 1954 - 1962.

respectively. However, the Inland Fisheries Decree (1992) makes a single provision empowering the Ministerin charge of Fisheries matters to determine whether the setup of enclosures, such as pens and cages, should be subject to a license fee.

One of the effective methods of managing the living resources in Nigerian marine and fresh waters is the enforcement of Fisheries regulations and laws. This will prevent over-exploitation of the living resources and prevent the polluting of the waters as well as provide high quality fish for consumption by the Nigerian masses. For any Fisheries regulations to be effective there must be appropriate enforcement agencies that would meaningfully realize the goals of such regulations.

THE WAY FORWARD: TOWARDS CONSERVATION AND UTILIZATION OF SEAFOOD

Efforts so far

i. Much regulations have been put in place so far to ensure the protection of the environment by oil companies. Beyond the local, state, national/federal regulations on environmental protection, Nigeria is a signatory to a number of conventions and agreements on environmental protection. Moreover, there is duplicity of administrative framework for environmental protection in Nigeria. What is lacking is the political will power to enforce existing regulations.

ii. The proposed Petroleum Industry Bill (PIB) will be another great improvement in the conservation and management of natural resources in Nigeria, if properly fine-tuned, finally passed and effectively implemented. If properly fine-tuned, then PIB is drafted by the operators and will be implemented by the operators. Apart from the operators and the political class, no other sector of the economy in Nigeria (academia or any other enlightened group) has ever reviewed the PIB to ensure that it addresses all the issues it should address for the benefit of all.

iii. While so much work has been done on the legal and administrative framework for conservation of natural resources like seafood in Nigeria, failure of the operators of oil companies to adopt the 'Principles of Responsible Business Practices of the United Nation's Global Compact (UNGC)' during her operations is the reason for the huge effects of petroleum E and P activities on seafood production and management in Nigeria.

iv. A number of studies have been carried out towards the conservation and utilization of seafood in West African and Nigerian waters in general and lower Qua Iboe River Estuary in particular (Edmund, 1978; Ifon and Umoh, 1987; Udotong and Sokari, 1998; Sokari and Udotong, 1998).

Regulatory framework should be put in place towards conservation of Seafood as natural resources

i. Since seafood are renewable resources, adequate legal and administrative framework should be put in place for natural resources damage, assessment and restoration similar to that which has been in place in the case of the Deepwater Horizon Oil Spill in the Gulf of Mexico. In the midst of several oil spill cases into fishing grounds, there has been no instance of closure and re-opening of fishing grounds after pollution of such fishing grounds in Nigeria. There is need for regulatory framework to take care of this and many other issues on conservation of seafood resources.

ii. During oil spill incidences in Nigeria, rates have been specified by Oil Producers Trade Section (OPTS) of the Nigerian National Petroleum Corporation (NNPC) as compensation for each economic crop damaged, in an attempt to conserve these crops. Similarly, there is need for regulatory framework to specify the rates for compensation for seafood destroyed, if these important natural resources must be conserved.

iii. The focus of the regulation on "Oil in navigable waters" is not on the conservation of seafood as natural resources. Moreover, it is hardly enforced in Nigeria to ensure that seafood are conserved. Effective enforcement of the regulation on "Oil in navigable waters" will help to conserve seafood as natural resources in Nigerian waters.

Much more stringent measures should be adopted to prevent pollution

i. Fishing grounds are usually polluted by the release of under-estimated or unknown volumes of crude oil and/or petroleum wastes streams into water bodies either

deliberately or during oil spills as a result of equipment failure, sabotage/bunkering, during loading, etc. Till date, actual daily petroleum production volumes from each of the oil wells are not known. Oil spill volumes can not be accurately estimated. Wastes streams from each production facility are grossly under-estimated and efficient treatment and disposal cannot therefore be effectively planned.

For effective planning and management, we propose that each oil well be metered to ensure that the actual petroleum production volume as well as wastes streams generated and released to the environment are known. If we can meter water, petroleum products, electricity in Nigeria, we can meter crude oil production from each well.

ii. The fines attracted by violations of environmental pollution e.g. fines for gas flaring, etc are so meager that it is much more economical to violate and thus pay the fines than to comply with the guidelines. To encourage compliance, a much more stringent measure is necessary.

Stakeholders awareness/sensitization and training is key to conservation and utilization of seafood

There is the need for awareness/sensitization of stakeholders on the effects of petroleum E and P activities on seafood production and management with a view to conserving and utilizing seafood as sources of cheap and available protein. Regulators need to be trained on natural resources damage, assessment and restoration (like closure and re-opening) of fishing grounds as well as seafood standards and specifications.

Proponents of petroleum E and P projects should institute corporate social responsibility (CSR) projects to encourage seafood production and management

Proponents of petroleum E and P projects should be encouraged to adopt seafood production and management projects e.g. fish fingerlings production and distribution, shrimp and other seafood production, etc as community development projects in riverine communities. This corporate social responsibility (CSR) project will obviously project the company as a socially responsible corporate citizen.

The Green River Project (GRP), a Unit in the Corporate Sustainability Department of Nigerian Agip Oil Company (NAOC) Ltd, Port Harcourt had set a pace in this direction with the establishment of fish fingerlings production and distribution to residents of host communities both in the swamp and land areas of their operational areas.

Integration of biodiversity and ecosystem services (BES) into petroleum E and P operations

Proponents of petroleum E and P projects should be compelled to integrate biodiversity and ecosystem services (BES) into petroleum E and P operations. By this, biodiversity and their ecosystems including seafood and aquatic ecosystems will be protected from the effects of petroleum E and P operations.

Conclusion

The effects of petroleum E and P wastes streams and oil spills, as well as other activities on seafood are enormous and cannot be over-emphasized. It ranges from physical contamination leading to poor seafood health and quality, which will manifest in tainting, through the manifestation of its toxic effects on seafood stock and to extinction due to non-spawning or over-exploitation and death of eggs, larvae, juveniles and even the adult seafood as a result of pollution. The spiral effect of the aforementioned on the disruption of other socio-economic activities particularly the distribution/market chains cannot be over-stressed as it can lead to loss of sources of livelihood. This can be serious to fishermen and fish marketers in riverine communities.

It is important to note that the detailed and specific nature and extent of impacts of petroleum E and P activities on the production and management of seafood is dependent on the characteristics of the spilled oil, the circumstances of the incident and type of the fishing activity or business affected. To reduce the effects to as low as reasonably practicable (ALARP), a well articulated and effectively implemented emergency response plan that addresses fish closures and re-opening, as well as other oil spill response measures can prevent or reduce the impact of oil spills on seafood. This document is sometimes referred to as the 'Oil Spill Contingency Plans (OSCP) (Udotong, 2017). This and many other suggestions to mitigate the effects of petroleum E and P activities on seafood have been proffered in this article as a way forward in conservation and utilization of seafood.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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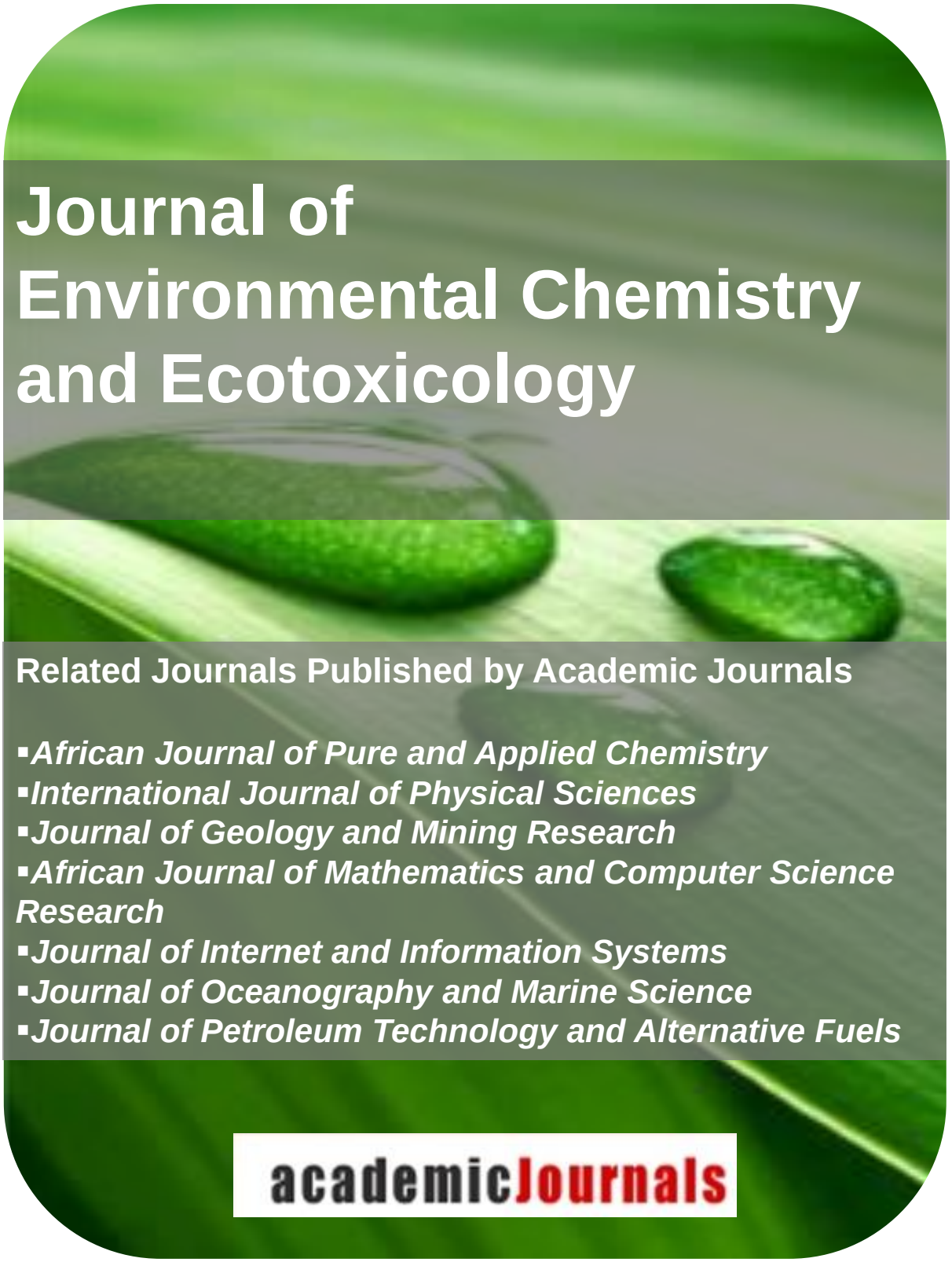

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