

ASSESSMENT OF ENVIRONMENTAL IMPACTS AFTER EXXON-MOBIL OIL SPILL ON THE CONTINENTAL WATERS OF THE GULF OF GUINEA, NIGERIA, W. AFRICA.

ITA EWA-OBOHO and F. EMILE ASUQUO

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ABSTRACT

On January 12, 1998, a 24-inch crude oil pipeline linking Idoho offshore platform and the Exxon-Mobil Qua Ibo terminal facility onshore, ruptured on the inner shelf of the Gulf of Guinea, S.E. Nigerian coast. The consequences was the release of over 40,000bbl of Nigeria crude oil into the sea. More than 700km length of the coastline including the mangrove swamps were oiled. Cleanup and containment equipment and dispersant were immediately deployed in quick response to the spill. Movement of oil slick was westward along the direction of prevailing winds, current and waves and stranded large quantities of spilled oil ashore on Brass, Forcados, Escravos and Lagos Lagoon coastal shores. Environmental impact studies to determine the acute effect of the spill commenced 24 hours after and the components studied included fisheries, benthos, chemistry, plankton, for both offshore and riverine/estuaries compartment of the aquatic environments. Mortality of aquatic bio-communities was not apparent immediately after spill, though planktonic organisms along spill track showed reduction in cell counts when compared with counts in the non-oiled zones. Benthic communities showed no significant population changes from unimpacted areas and mean population densities were generally low. The pelagic food fish and shell fish species such as *pseudolithus elongatus* and *Callinectes amatum* caught in the area one week after the spill recorded high accumulation of petroleum hydrocarbons in body muscles.

KEY WORDS: Environmental impacts, oil spill management, Idoho oil spill, Gulf of Guinea, Nigeria.

INTRODUCTION

A 24-inch crude oil pipeline ruptured at Exxon-Mobil-Idoho offshore platform on 12th January, 1998, releasing an estimated 40,000bbl of light crude into the marine environment over the inner continental shelf of the Gulf of Guinea off the Atlantic coast of Nigeria. Many adjoining mangrove swamps, lagoons and estuaries were oiled. Rapid clean-up and containment response was undertaken by Exxon-Mobil Oil Company, Government and non-governmental agencies within 24 hours of the spill.

Weather conditions enhanced an efficient and immediate technical response such as the use of floating booms though the prevailing winds during this period tended to spread the oil westward, and current interplay stranded oil ashore (Conomos 1979, Smith 1982). The ecological and economic impacts of what is still the biggest accidental spill in the Guinea Gulf region, is still being investigated and monitored for long-term effects and recovery (Ewa Oboho, 1999). Similar incidents of oil spills into the aquatic systems have been documented worldwide. For instance, a 42" pipeline ruptured and released over a million gallons of diesel fuel in Greenville South Carolina in 1996 while an oil tanker ran into a bridge and spilled 180,000 gallons of fuel oil in Portland Maine in 1996. Similarly, at Paulsboro New Jersey, a vessel lost 256,000 gallons of crude oil in 2005 and also at Baytown, Texas, a vessel hit at dock released 1,500 barrels of VTO into the waters.

The objective of the present study was to assess the fate and effects of the known quantity of the Nigerian light crude on the tropical continental shelf waters and their adjoining mangrove swamps. This will provide a basis for future studies, since this region is a major oil producing area and therefore, very susceptible to oiling. Moreover, the spill site at Idoho platform is one of the best-characterized sites of its kind in the world. The present paper describes the clean-up strategy adopted and the elements and findings of the acute effects of the spill based on field investigations

MATERIAL AND METHODS

The study area

The Idoho-offshore platform is located at approximately 120m deep on the inner continental shelf of the Gulf of Guinea (4°30'N: 8°00'E) (Figure 1). The salinity of the water is 25.6‰ at the surface and < 9‰ at 120m depth, while temperature is 29° C at surface and < 26° C at bottom (Asuquo, 2004). The region is exposed to benthic storms for several days during the rainy season (June -October) during which daily-averaged near surface currents velocities could exceed 18cm/sec.

Periodic tidal waves and non-periodic wind generated currents and storms play a very important role in the transport and redistribution of materials in the coastal marine waters. Swells generated by storms (South West Monsoon) reach the coast with periods varying between 6 to 13 seconds

with an average of 10 to 12 seconds. Wave heights in this area averaged 1.5 meters. However heights of 2 to 3 meters occur especially during the stormy months (June-October). The coastal features of the spill region include a strand coast at the eastern flank from the Imo River boundary across the Cross River estuary to the Nigeria/Cameroon boundary (border) and is characterized by mud and predominantly fine-grained sand. The residence time of stranded oil is short (ca 30 mins) since the area is dominantly a high-energy environment. There is also a barrier-lagoon coast, which extends 250km eastward from the border of Nigeria-Benin Republic connecting many rivers and creeks and finally joined the sea through Lagos harbour. The sediment varies from medium to coarse sand.

The Niger-Delta region is characterized by a large expanse of mangrove coastal wetlands and some exposed sand shorelines. An intricate network of rivers, creeks and water pools bordered by species of mangrove plants are common features of the shelter zones of the delta region. These are the most productive regions of the world in terms of fisheries resources and therefore very sensitive and vulnerable to an oil spill. There is also the Mahin-mud coast, which consists of extensive mud flats bounding low lying coastal

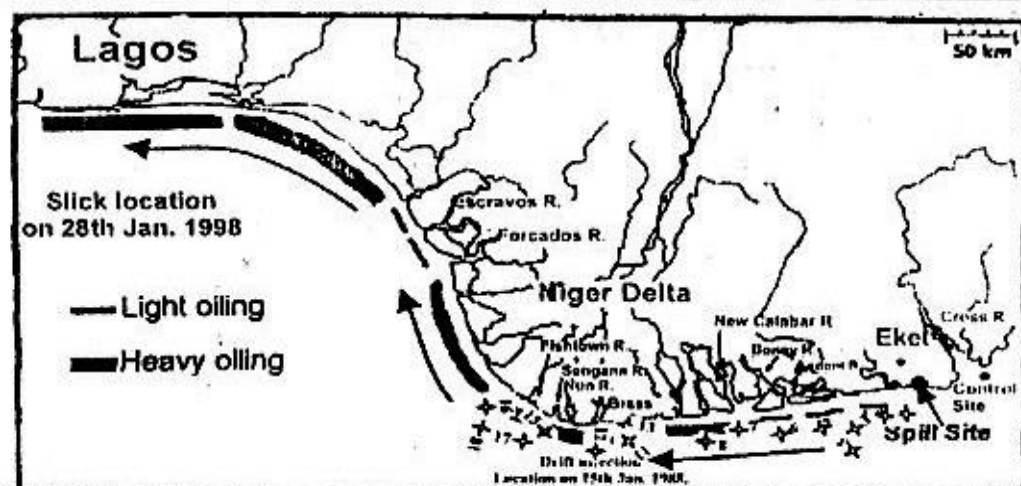


Fig. 1: Map of the Nigeria coastline showing the spill site, drift route, the level of oiling and the Environmental Sensitivity Index (ESI) Map of the Nigerian coastline.

creeks with mangrove species dominating the plants. This could retain spilled petroleum for a rather longer period due to the muddy sediments.

FIELD SAMPLING TECHNIQUES

Sediment and water samples were collected with Van Veen grab (0.1m²) and rosette water sampler respectively, at stations established along a transect parallel to the oil trajectory. Samples were collected at distances of approx. 10km apart. For benthic investigation, five replicates of sediment were collected and washed through a 1mm aluminum sieve at each station, and the residue labeled for sorting and identification of organism in the laboratory. Plankton net was towed at 5-6 knots for 5 min for plankton sample collection at each transect. Samples were labeled and fixed for laboratory identification.

Sediment samples for enumeration of bacteria were obtained with a sterile plastic syringe cut in the end to enable plugging out small sediment cores of the upper 5cm of the sediment obtained from sediment core sample. Samples for enumeration of bacteria in the water were taken by means of a sterile glass syringe equipped with a 1.0 µm pore size filter to separate other particles from the water. Intact sediment core for activity measurements were logged out by means of sterile glass tube (id. 25mm, length 250mm). All microbial samples were brought to the laboratory and processed within 3 hours. Enumerations of total heterotrophs was estimated by the plate-spread technique (APHA, 1998). Duplicate sediment samples from 5 core samples were diluted in filtered sterile sea water. One tenth of selected dilutions was pipetted onto a pre-dried PCA medium (Boucher *et al.*, 1984). All plates were incubated at ambient temperature of 28°C for two days before counting. Accepted range for counting were 30-300 colonies/plate. Hydrocarbon utilizing bacteria were counted in the same way on a mineral salt medium with Nigeria light crude oil added to the medium in a concentration of 2mg/l and estimated by the most probable number (Walker and Colwell, 1976).

The hydrocarbon-degrading activity in the sediments was measured as mineralization of ¹⁴C-hexadecane in intact sediments cores. The qualitative determination of hydrocarbon concentration in sediment samples was carried out on hexane extracts using fluorescence spectroscopy (Perkin Elmer 3000), with Nigerian Light Crude as reference. A total of 10 beach sites were sampled for oil effects on the intertidal elevations along transects. Investigations included hydrocarbon analysis of sediments, water and fauna.

RESULTS AND DISCUSSION

Table 1 shows the types and quantity of dispersants applied during the spill containment programmed. From day 1 of the spill (12th January, 1998) to day 4 (15th January, 1998), cumulative quantities of Gold/Crew Brand of dispersant were applied to the spilled oil. This geometric daily increase in dispersant quantity applied was necessary considering the fact

Table 1. Cumulative dispersant applied during January 12-18, 1998 Idoho off-shore crude oil spill.

Date: January, 1998	Cumulative Quantity of dispersant applied (bbls)	Types of dispersant applied
12	9	Gold Crew
13	40	Gold Crew
14	76	Gold Crew
15	140	Gold Crew
16	212	Gold Crew Core exit 9500
17	233.5	Gold Crew Core exit 9527
18	2355.	Core exit 9500 & 9527 Core exit 9527

that mousse formation can render dispersants ineffective due to the difficulty of penetration of dispersant into the mousse and to its rapid removal from the mousse surface into the water column by waves and sea surface turbulence (Boucher *et al.*, 1984). The impact studies aimed at investigating the short-term effect of the spill on two major components: the offshore and the river estuaries, both of which were designed to detect the acute effect of the spill on water and food resources of the coastal inhabitants.

Table 2 presents the sediment composition, organic carbon content and total hydrocarbon in the spill area. The sediment, which composed of fine muddy sand, could only support a limited population of macro fauna despite the high organic food content. This is attributed to the anoxic condition brought about the depletion of dissolved oxygen utilized in the biodegradation of high organic matter in sediment. Low benthic count could also be associated with the clogging potential

Table 2. Sediment composition, organic carbon and total hydrocarbon in spilled area (IDHO-Sangana), January 1998.

Component	GPS. Coord. Long /Lat.	Clay %	Silt %	Sand %	Organic Carbon %	Tot. Hydrocarbon mg/kg
Control	4°28'N 7°59'E	2	20	78	18.5	5.0
ID 1	4°25'N 7°48'E	5	20	75	20	9.4
ID 2		4°29'N 7°58'E	6	22	70	18.6
ID 3	4°24'N 7°50'E	12	30	68	25	13.0
ID 4	4°21'N 7°39'E	5	12	83	35.5	-
ID 5	4°22'N 7°39'E	5	10	85	11.6	12.4
ID 6	4°22'N 7°3'9'E	5	4	50	30	-
ID 7	4°23'N 7°29'E	20	15	65	22.2	-
ID 8	4°22'N 7°24'E	20	30	50	25.6	-
ID 9	4°4'N 7°9'E	12	31	57	295	9.4
ID 10	4°10'N 7°05'E	25	30	45	32.6	-
ID 11	4°15'N 7°03'E	20	25	55	281	-
ID 12	4°17'N 6°53'E	10	15	75	9.6	-
ID 13	4°16'N 6°36'E	12	32	57	20.5	-
ID 14	4°14'N 6°26'E	25	40	35	36	-
ID 15	4°12'N 6°15'E	5	45	50	325	-
ID 16	4°12'N 6°04'E	10	25	65	26	-
ID 17	4°16'N 5°54'E	15	65	30	38.5	-
ID 18	4°10'N 6°40'E	10	10	25	42	-

of the fine silt particles. Feeding and respiratory structure of invertebrates were in the peril of being readily clogged by fine silt. Although some oil was detected within 24 hours of spill in sediment, the impoverished faunal density could not be directly related to oil presence, since mortality of benthic fauna was not noticeable immediately after the spill when investigation was carried out.

However, from day 5 of spill to day 7, stronger combinations of dispersants (Gold Crew, Core Exit 9500 and Gold Crew exit 1527) were applied to spilled oil. Thicker lenses or patches of oil were observed to move along the leading edge of slicks, and dispersants were more effective when applied directly to the thicker lenses rather than the trailing sheen or thinner slick. During the clean-up operation offshore, pumping efficiency was greatly enhanced by injection of demulsifiers together with dispersants into oil/mousse mixtures.

The distribution of plankton along the leading edge of slick is shown in Table 3. Plankton densities were generally low along the route. Phytoplankton densities varied from 10 individuals/litre at the spill point (4° 27' N; 7° 45' E) to 50 individuals after Brass (4°12'N;6°15'E) about 200km from the spill point. Zooplankton also showed density fluctuation spatially along the spill route. Around the spill point, densities ranging from 2-5 individuals were recorded, while values as low as 3 individuals and as high as 30 individuals/litre were observed kilometers away from the spill zone.

Plankton diversity and population densities were generally higher in the control station (200 individuals/litre) which was located 5km east of the pipeline rupture point compared to plankton abundance along the spill route. A checklist of dominant planktonic organisms in Nigerian coastal waters during the spill period is presented in Table 4, the dominant phytoplankton species included *Microcystis*, *Lyngbya*, *Coccolodiscus* and *Perenema*.

The zooplankton were mostly fish eggs, crustacean larvae and a few copepods. The generally low planktonic densities along the slick route could be attribute to reduced light penetration into the water column, caused by oil slick and sheen. This may have caused phytoplankton species to drop out of the photic zone into the deeper aphotic region. During the daytime, zooplanktonic forms operated at deepest levels to avoid predation. Also shadow cast from drifting oil perhaps induced photophobic response, which took zooplankton species further down from the near surface region (Gwilliam, 1962; Forward, 1976, 1977; Moore and Cobb, 1985). Direct toxic effect of crude oil on phytoplankton in offshore spill are rare since most chrysophytes and chlorophytes have the capacity to accumulate and metabolize both aliphatic and aromatic compounds from crude oil (Thompson and Eglinton, 1979). As sunlight penetration is restricted by surface slick, primary productivity of continental shelf waters along the oil route would have probably decreased. But this was not the case rather there is an agreement similar to the observations

Table 3. Plankton density along spill route, January, 1998.

Location (co-ordinate)		Diversity (No of species)	Density (no of individuals)	Diversity (No of species)	Density (No of individuals)
4°28'N	7° 59'E control	16	200	4	35
4°28'N	7°48'E	1	10	2	5
4°29'N	7°58'E	5	20	2	2
4°24'N	7°50'E	5	10	3	10
4°21'N	7°39'E	9	20	2	10
4°22'N	7°39'E	1	10	3	5
4°22'N	7°39'E	7	20	4	30
4°23'N	7°29'E	2	10	4	6
4°22'N	7°24'E	-	-	-	10
4°4'N	7°9'E	3	0	3	-
4°10'N	7°05'E	2	10	3	10
4°15.5'N	7°03'E	3	20	2	10
4°17'N	6°53'E	5	10	1	5
4°16'N	6° 36'E	4	20	3	3
4°14'N	6° 26'E	6	30	6	10
4°12'N	6° 15'E	3	50	4	3
4°12'N	6°04'E	3	30	1	16
4°8'N	6° 54'E	1	20	2	4

Table 4. Checklist of dominant plankton in Nigerian coastal waters during the study

Class	Phytoplankton	Zooplankton
<u>Division</u>	<u>Chlorophyta</u> <i>Coscinotium abhorarum</i> Bech <i>C. Moniliforme</i> (Turpin) Ralfs <i>C. Pochydrum</i> Luna <i>Desmidium Swartzii</i> Ag. <i>Pediastrum simplex</i> (Meeper) Lemm. <i>P. Doryanum</i> (Turpin) Menegh <i>P. Simple</i> Meyer <i>Scenedesmus Accumianus</i> <i>Tetradon</i> Sp	<i>Brachionella</i> Sp <i>Kerucella</i> Sp <i>Copepoda: Cyclops</i> <i>Diptomus</i> Sp <i>Fish eggs</i> <i>Paracalanus</i> Sp
<u>Division</u>	<u>Bacillariophyta</u> <i>Coscinodiscus centralis</i> Her <i>Coscinodiscus rotulii</i> <i>Cyclotella meneghiniana</i> Kutz <i>Cyclotella bodanica</i> <i>Pseudostrum</i> Sp <i>Amphora exigua</i> Ersmov <i>Cocconeis Placentula</i> Her <i>Comptonema Lunolata</i> Her <i>Synosigma Scalprade</i> (Ralfs) Clave <i>Nitzschia filiformis</i> (Wisn) Husteik. <i>Pinnularia borealis</i> Her <i>Symedra capitata</i> <i>Symedra ulna</i> Her	
<u>Division</u>	<u>Cyanophyta</u> <i>Oscillatoria</i> Sp <i>Lyngbya, Sp. microcysts</i>	

indicating increased productivity such as during the Bravo spill (Lannergren, 1978), the Tæsis spill (Johansson, 1980), Torrey Canyon Spill (Smith, 1970) and Bunker C oil from the Kurdistan (O'Boyle, 1980).

Zooplankton also accumulate and metabolize crude oil components and can survive offshore spillages. But persistence of oil fractions in their biomass even after depurations could be a significant factor in the transfer of hydrocarbon or their metabolites to higher trophic levels and pose long term consequences for aquatic food chains.

MICROBIAL BIOMASS ALTERATION

The observations in this investigation confirm earlier findings concerning microbial dynamics in oil polluted sediments (Atlas, 1982; Gassman and Gimkel, 1983; Traxler

and Vanderveulen, 1981). In all the sites along the slick route, both the hydrocarbon utilizing bacteria and the heterotrops showed an initial marked decrease in number, which probably was due to a toxic effect of the initial high concentration of oil in off-shore waters. After 1 day, the effect seem to be neutralized by the system and a rapid increase in bacteria numbers occurred (Fig 2). Similar patterns for the control indicated a minor or minimum contamination with oil.

Chemical dispersants applied on offshore waters to contain the oil did not seem to have affected biodegradation of oil. The fact that there was initial decrease in numbers of micro-organism within the first 10-12 days of spill, followed by rapid bloom compared to non-impacted

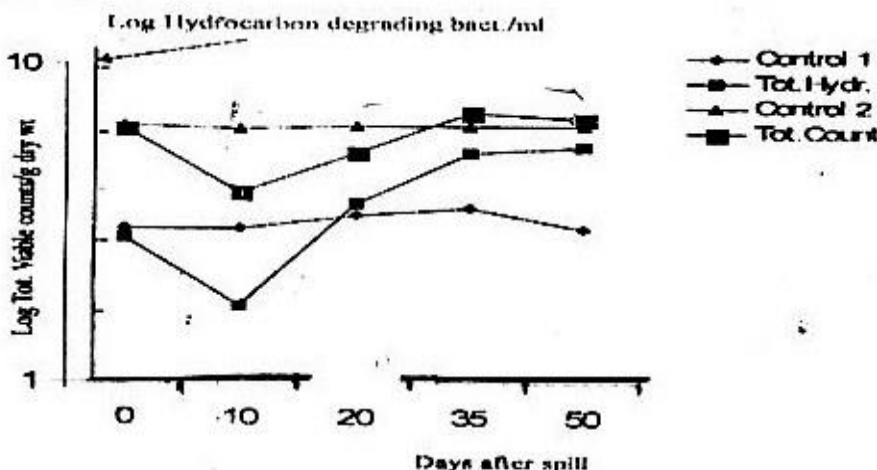


Fig. 2: Variation in the number of total hydrocarbon degrading bacteria and total viable bacteria count in the oiled areas (Contr. 1 and 2 represents controls for degrading bacteria and viable bacteria counts respectively).

natural ecosystems, inferred little or no effect of applied dispersant. The reason could be that, the products are highly water-soluble and are dispersed or diluted within a short time of application by the huge volume of the offshore water. Further more the use of such agents might increase the sinking of oil and its percolation into the sediments

BENTHIC STUDIES

A total of 225 macrobenthic fauna distributed among 36 species were found in samples collected along the transect. The faunal composition of the spilled region 48 hours after the spill and 1 year before the spill incident are compared and presented in Table 5. Data before the spill were collected during a sea bed survey in 1997. Values are taxa percentage contributions to the mean total number of macro faunal individuals in the sample unit of each study. Percentages whose differences are not significant at the 95% confidence level are jointly underlined. Polychaetes dominate the macrobenthic numerically accounting for over 55% of the individuals with a maximum of 60%.

The best represented families in order of relative abundance were the *Spionidae* (13) species, followed by *Ophelidae* (12), *Cirratulidae* (9), *Magelonidae* and the *Naphtyidae* (3). The second most dominant were the crustaceans, which were represented by a number of species. Species of *Pseudonictis*, *Byblis* and *Rhopoxinus* and the relative proportions of dominant crustaceans: the tanaids, isopoda, amphipoda and cumaceans fell within the range obtained in earlier sea-bed surveys in the region (Ewa-Oboho, 1994). The number of individuals ranged from 0-15 per station while the biomass ranged from 0-3.5 g/m².

No significant difference ($p > 0.01$, F-test on ANOVA) was found between control site (5km east of the ruptured point) and those along the spill route. This probably could be due to stability of the offshore sediment in this area as indicated by the consolidated state of the mud substratum allowing for equilibrium existence of benthos and probably the fact that spilled oil at sea takes awhile to be transported and trapped into sediment. The bulk of organic materials in sediments (excluding the fauna) in the study area is derived by sedimentation from the overlying water column. This forms the basic food resources for the benthos. The identities of the species collected and their proportional representations showed little variation between cores. Similarities were apparent when the percentage of representation of the major taxonomic groups were compared with the comparable data from studies before the spill.

Short term effects of oil on macrobenthos was not immediately apparent probably because most macrobenthos can accumulate crude oil components in their tissues to very high concentrations (Rossi and Anderson, 1977; Widdos et al, 1982; Augenteld et al, 1982; Borgman et al, 2001; Ogric et al, 2001; Borgman and Norwood, 2002; Asuquo et al, 2004). This is particularly the case with suspension feeding bivalves and deposit feeding polychaetes. Secondly, the quantity of spilled oil accumulation at the bottom within 48 hours of the spill may not have been enough to cause immediate disaster for the benthos and thirdly, plume of crude oil component from the discharged point along along the bottom may have been disrupted and dispersed by waves and high tidal currents prevalent in these areas which might have made fine suspended particles of reactive oil pollutants to remain in

Table 1. Benthic Fauna composition of the oil spill region (inner middle continental shelf of the Gulf of Guinea) post spill compared with data before the spill in 1995

TAXON	48HR POST OIL SPILL 1998	1 YEAR BEFORE OIL SPILL 1997
Polychaeta	59.2	59.5
Oligochaeta	2.8	-
Sipuncula	0.5	1.2
Nemertea	-	2.8
Polychaeta	-	2.1
Tanaidacea	18.4	9.0
Isopoda	0.5	4.8
Amphipoda	15.0	18.0
Cumacea	-	0.5
Aplicophora	0.8	0.0
Brachia	2.2	9.5
Gastropoda	0.4	0.9
Scaphopoda	2.8	1.2
Ophiuridea	0.2	2.3
Echinidea	-	-
Ascidacea	0.9	0.1
Mollusca	-	-
Bryozoa	2.0	0.8
Ascidacea	1.2	0.1

* Percentages whose differences are not significant at the 95% confidence level are jointly underlined.

constant resuspension. Rapid discovery of benthos from oiling effect in the warm waters may have been facilitated by the life story characteristics of possessing short generation times and broader dispersal abilities.

INSHORE INVESTIGATIONS

The adjoining estuaries and rivers are breeding and nursery grounds for most fish species of continental shelf origin and oiling effect was assessed based on the tissue concentration

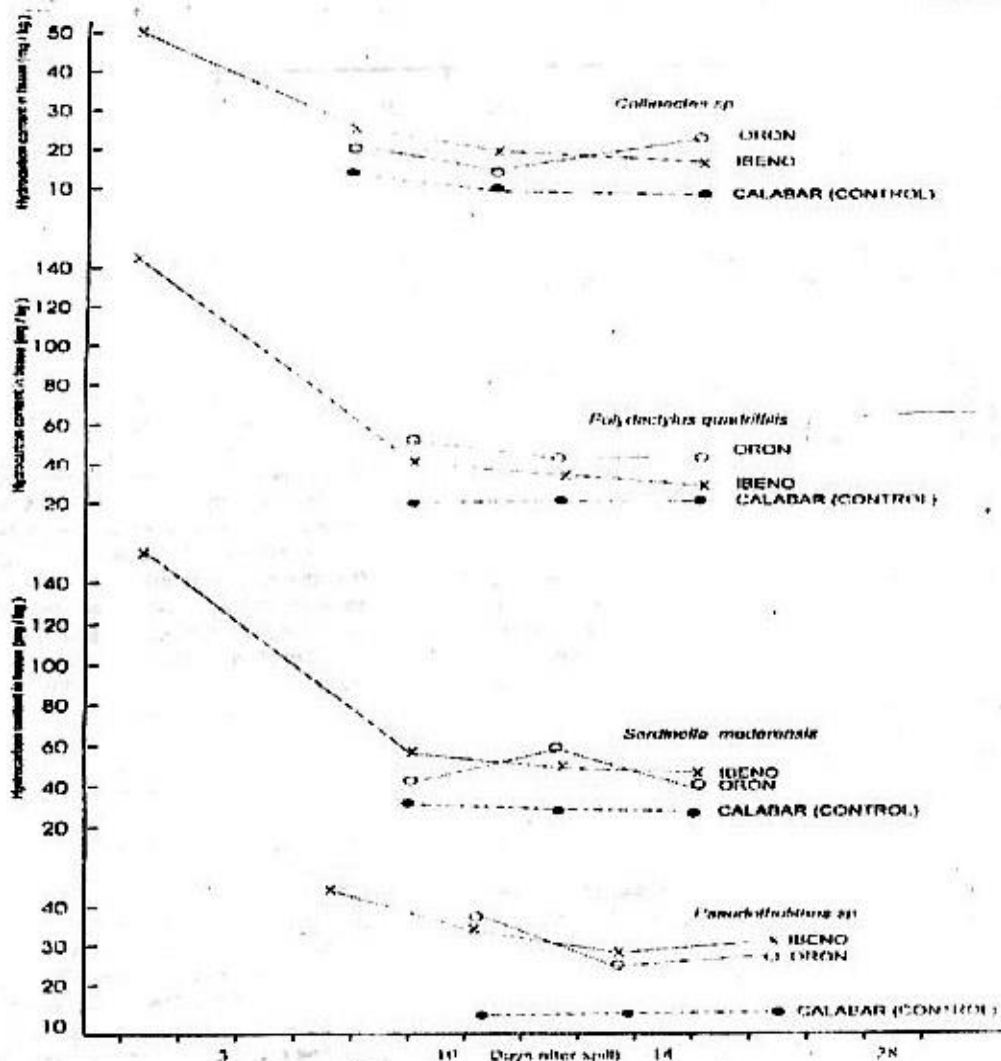


Fig. 3: Levels of THC in some food fish species in the oiled areas of Ibeno and Oron, 28 days after the spill.

of dominant food fish species in the area. The hydrocarbon levels in the pelagic fish species caught 3 – 5 days after the spill in the oiled areas of Ibenu and Oron are illustrated in Fig. 3. In all species studied in the oiled and non-oiled areas (Table 6), values of THC were higher than United Nations 25mg/l or 25ppm threshold for hydrocarbon in the fish (Asuquo and Udoh 2002; Asuquo *et al.*, 2004), thus posing a public health

threat to the food resources of the local inhabitants. Levels of total hydrocarbon (THC) monitored for 28 days after the spill in the common swimming crabs (*Callinectes sp*) and fin fish species, *Polydactylus quadrifilis* all showed reduction in tissue hydrocarbon towards normal levels (Fig. 3). Reduction was perhaps due to depuration and excretion (Gwilliam, 1965; Forward, 1976).

Table 6: Food fish tissue analyses in the oiled areas of Ibenu and Sangana 1998 values are means for twenty five specimens in each taxa.

Test-organism	Hydrocarbon content in tissues (mg/kg)	
	IBENO	SANGANA
<i>Pseudotolithus sp</i> (croaker)	36.32 ± 1.8	58.64 ± 1.2
<i>Sardinella maderensis</i>	107.5 ± 1.6	69.8 ± 2.8
<i>Polydactylus quadrifilis</i>	139.3 ± 2.1	126.1 ± 2.5
<i>Callinectes sp</i> (swimming crabs)	48.98 ± 2.6	29.65 ± 1.8
<i>Thais califera</i> (Whalk)	68.31 ± 2.1	102.62 ± 3.1
<i>Grassostrea tulipa</i> (mangrove oyster)	230.12 ± 1.5	03.83 ± 2.4

CONCLUSION

Application of dispersion agents in adequate quantities at spill site prevented extensive shoreline oiling. This reduced the damage on sensitive bio-habitats along the shore areas. Mortality of aquatic bio-communities was not apparent immediately after spill, though planktonic organisms along spill track showed reduction in cell counts when compared with counts in the non-oiled zones. Acute effect of crude was not noticeable in the benthos, as no significant differences was obtained in the identity and percentage representation of major taxa collected 48hrs after oiling and 1 year before. Though the initial levels of hydrocarbon in food fish tissues were high and threatening to public health, concentrations reduced to WHO permissible limits 28 days after the spill.

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