CHAPTER 9

ENVIRONMENTAL POLLUTION FROM ETIAMA OIL SPILL – BAYELSA STATE NIGERIA

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Abstract

On 13th May 2000, the 24" Ogoda – Brass pipeline belonging to Nigerian Agip Oil Company (NAOC) was ruptured by sabouteurs using dynamite resulting in the spillage of about 11,000bbls of crude oil into Etiama village and the neighbouring communities in Nembe Local Government Area of Bayelsa State. Attempts to staunch the ruptured pipeline resulted in a fire incident on 20th May 2000 affecting about 1.2km stretch along the pipeline right of way, (ROW) resulting in loss of lives. About 70km² estimated to be the total size of the spill site, approximately 20km² of this land area is occupied by rainforest vegetation while the remainder is dominated by the mangrove forests. The level of nutrients in surviving plants in the Etiama oil spill site was used as an index of the state of the environment as changes in the environmental physico – chemistry affects the nutrient uptake capability of plants in that environment. Concentrations of sodium, phosphate, potassium and calcium found in surviving plant tissues were significantly above the upper limits of concentration ranges generally encountered in plant tissue. On the other hand, concentrations of zinc and iron in the Etiama plant tissue samples were significantly lower than the expected concentrations ranges. Total hydrocarbon (THC) content of surface soil within the spill site ranged between 72 – 5438mg/kg with an average of 1358.5mg/kg. Poly – aromatic hydrocarbon (PAH) was only detected at one sampling station at a concentration of 0.05mg/kg. It was observed that hydrocarbon utilizing bacterial species constituted about half the total population of heterotrophic bacteria in the soil samples. The environmental status of the Etiama oil spill site as at 6th – 10th May 2002, about two years after the oil spill has been reviewed. Moreover, the guidelines for management of mystery oil spills and liability and compensation arising therefrom as set out by Department of Petroleum Resources in Part VIII B Section 4 and 8 of the Environmental Guidelines and Standards for Petroleum Industries in Nigeria is herein highlighted.

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1.0 Introduction

The Etiama oil spill incident occurred on 13th May 2000 when the 24" Ogoda – Brass pipeline belonging to Nigerian Agip Oil Company (NAOC) ruptured. The incident resulted in the spillage of about 11,000 barrels of crude oil into the environment. The point of the spill is located near Etiama village in Nembe Local Government Area of Bayelsa State. The cause of the rupture is still uncertain. However, a speculation, by an investigation/contingency response team including the officials of Bayelsa State Environmental Protection Agency, is that saboteurs ruptured the pipeline with dynamite.

On 20th May 2000 a fire incident occurred during attempts to staunch the ruptured pipeline. The fire affected about 1.2km along the pipeline right of way (ROW). It was reported that lives were lost in the fire but the actual number has not been confirmed.

The spill was prevented from moving further inland, along the pipeline trench, by a sand dam built to bridge the footpath. Southwards, along the pipeline trench, the oil slick traveled about 2.5km into Osuma Creek. Within this distance, the spill affected about 7 – 10m of land and mangrove vegetation on either sides of the pipeline. However, the pipeline trench prevented the oil from spreading sideways into the hinterlands.

The oil slick drifted from the pipeline ROW into Osuma Creek and traveled about 3km along the meandering creek, aided by the receding tide, into Agbakabiriya Creek. All of the nearly 7km of Agbakabiriya Creek and village were heavily affected by the spill. The oil slick traveled on through Agbakabiriya Creek to Nembe Creek and gained access to the web of creeks and creeklets that drain the entire area.

On land, the spread of the spill was generally restricted to the banks of the waterways (not exceeding 15m inland on either side at any one point) and the tidal mudflats on which substantial quantities of the oil were deposited.

NAOC's oil spill contingency plan was activated in line with Federal Ministry of Environment (formally Federal Environmental Protection Agency, FEPA) and Department of Petroleum Resources (DPR) Guidelines and Standards on environmental pollution control in Nigeria (FEPA, 1991; DPR, 1991) and the leak was checked However, attending community issues did not allow for this to be achieved until nearly one week after the spill was first reported. It was also not possible to deploy booms and other containment equipment until after one week.

This chapter therefore seeks to highlight the environmental issues usually associated with oil spill incidents in Nigeria using the Etiama oil spill incident as a case study. The environmental status of Etiama oil spill site as at the spill and about two years after the spill are highlighted.

2.0 Environmental Issues Associated With Oil Spill

Table 1.0 below shows the Environmental components and Impact indicators usually employed in assessing the environmental impacts of oil spill incidents. However, due to the peculiar nature of the Etiama oil spill site, only major environmental components affected were considered.

Table 1.0: Environmental Components and Impact Indicators

S/N	Environmental Components	Environmental impact indicators
1.	Air Quality/Meterology	SPM, NOx, SOx, CO_2, CO, VOC, H_2S, etc.
2.	Water Quality (Surface Water)	Total solids (Dissolved solids, suspended solids); turbidity, other physico-chemical and microbiological characteristics, Aquatic toxicity tests, seabed sediment, physico-chemical / microbiological characteristics.
3.	Fisheries/Hydrobiology	Diversity, Abundance, productivity, catch/yield of fishes. Fish tissue analysis. Qualitative and quantitative information on benthos.
4.	Relief / Hydrology	Drainage / Discharge, Hydrologic balance, sedimentation, erosion, topography.
5.	Geology/Hydrogeology	Stratigraphical / Lithologic characteristics, ground water level and ground water quality (Physicochemical and microbiological characteristics).
6.	Soil / Land Use	Soil type and structure, physico-chemical and microbiological characteristics, land use types; recreational, industrial, agricultural, residential, institutional and commercial.
7.	Vegetation / Forestry	Species checklist, characterization of plant pollution, taxonomy, diversity and productivity load, locations and characteristics. Identification of types and economic importance of trees in the study area.
8.	Wildlife	Identification of wildlife types, parks, estimate population,

		behavioral pattern and habitat requirement; endangered species and ecological interactions.
9.	Noise / Vibration / Radiation	Ambient noise level. exposure limits of impulsive and persistent noise generated in the environment, the proximity of noise sources to human and ecological habitants; day and night disturbance. hearing loss communication interference.
10.	Health Risk Assessment	Health risks. public health and medical services, water supply and demand. analysis of medical records.
11.	Community/Socio-Economic Assessment	Needs and concern of host communities, Data on settlement, man-made features, socio-economic / historical rites, population, income, recreational facilities, social organizations and institutions, occupation and employment structure. culture, heritage, etc.

(Source: FEPA, 1995)

3.0 Environmental Status of Etiama Oil Spill Site

3.1 Terrestrial Ecology

The status of vegetation, soil, wildlife and water in the immediate vicinity of the spill are discussed in this section. These aspects of the assessment were carried out through sampling, analysis, still photography and interviews of the local people.

3.1.1 Vegetation

The Etiama oil spill site is located within an ecological zone that comprises of a mix of mangrove and rainforest vegetation. The area is characterized by a highly heterogeneous species composition.

The rain forest is concentrated in the upland area that lies to the north and north – east of the spill point. This area is able to sustain rainforest vegetation because of its elevated topography that precludes the locality from constant inundation by seawater. Tall but isolated emergent trees characterize this forest type, which is more heterogeneous.

The small crowns of the emergent trees from the upper canopy of the forest while the under story comprises of small trees bound together by woody climbers. The rain forest is a valued ecological components for it provides home for a wide variety of wildlife that

constitute a major protein and income source for communities in the area. In addition, the rain forest provides firewood and timber that are vital but scarce resources ion the area.

The remainder of the spill area is covered by typical mangrove vegetation dominated by the *Rhizophora* species. The highest density of the *Rhizophora* species is found just on the banks of the creeks and creeklets.

The mangrove vegetation is a valued ecological component because of its high productivity and because its prop (breathing) roots provide shelter for a wide variety of fish and other aquatic species with significant socio – economic and ecological values. The size of the mangrove forests within the spill area was estimated to be about 40km^2.

A conservative estimate of the total size of the spill site is about 70km^2. Approximately 20km^2 of this land area is occupied by rainforest vegetation while the mangrove forest dominates the remainder. The actual size of land area affected by the spill was estimated to be about 30km^2. This estimate covers the pipeline ROW, mudflats, and the mangrove forest on the banks of the creek and creeklets. The rainforests were not really affected by the spill because the tidal waters bearing the oil does not penetrate very far inland.

Samples of surviving mangrove vegetation were collected and the plants tissue analyzed for various nutrient elements. The level of nutrients in surviving plants in the Etiama oil spill site was used as an index of the state of the environment as changes in the environmental physico – chemistry affects the nutrient uptake capability of plants in that environment.

The average sodium, phosphate, potassium, calcium, zinc and iron concentrations in plant tissue were 2027.7mg/kg. 39.6mg/kg, 557.3mg/kg, 3815.2mg/kg, 12.7mg/kg and 126.5mg/kg respectively.

The concentrations of sodium, phosphate, potassium and calcium found in plant tissues were significantly above the upper limits of the respective concentration ranges generally encountered in plant tissue i.e. 3.0mg/kg, 3.0mg/kg. 50mg/kg and 25mg/kg (Allen, 1989). On the other hand, the concentrations of zinc and iron in the Etiama plant tissue samples were significantly lower than the expected concentrations ranges of 100mg/kg and 500mg/kg.

3.1.2 Soil

The status of soil with Etiama oil spill site was determined through sampling and testing for key physico- chemical and biological parameters including the total hydrocarbon (THC) and poly aromatic hydrocarbon (PAH) contents.

The ten (10) soil sampling stations were chosen based on a stratified sampling philosophy. Soil profile samples were obtained between depths of 10cm and 70cm from each of the two bore holes constructed for groundwater sampling. A control soil sample was collected at a station located about 30km from the spill site.

The pH of surface soil within the spill site ranged between 3.97 and 6.57 with an average of 5.36. The pH of samples collected from the subsurface (60 – 70cm depth) strata at the two borehole stations was 4.69 and 6.75 respectively. The pH of the sample collected at the control was 6.89.

The conductivity of surface soil samples collected within the spill site ranged between 87.0 and 434.0μS/cm with an average of 211.4μS/cm. The conductivity of subsurface (60 – 70cm depth) soil samples collected from the two boreholes stations was 75.1 and 1582.0μS/cm respectively. The conductivity of soil samples collected at the control station was 1294.0μS/cm.

The nutrient (calcium, potassium, magnesium, sodium, nitrate, phosphate and sulphate) contents of surface soils within the spill site ranged between 68 – 1208mg/kg, 274 – 1456mg/kg, 181 – 8485mg/kg, 15 – 223mg/kg, 5.62 – 7.81mg/kg, 8.4 – 24.5mg/kg and 100 – 250mg/kg respectively. The average nutrients content of soils were 298.1mg/kg, 695.1mg/kg, and 1327.1mg/kg, 65.3mg/kg, 6.82mg/kg, 12.83mg/kg and 142.5mg/kg respectively.

The concentration ranges of heavy metals (copper, lead, nickel and cadmium, arsenic, mercury, barium and iron) were <0.05 – 18mg/kg, <0.02 – 84mg/kg, <0.1 – 78mg/kg, <0.02 – 2mg/kg, <0.001 – 1.51mg/kg, 0.04 – 0.24mg/kg, <0.03 – 60mg/kg and 2219-27451mg/kg respectively. The average concentrations of these heavy metals in the surface soul samples were 6.67mg/kg, 38.2mg/kg, 25.6mg/kg, 1.4mg/kg, 0.94mg/kg, 0.11mg/kg, 22.0mg/kg and 9552mg/kg respectively.

The total hydrocarbon (THC) content of surface soil within the spill site ranged between 72 – 5438mg/kg with an average of 1358.5mg/kg. Poly – aromatic hydrocarbon (PAH) was only detected at one sampling station at a concentration of 0.05mg/kg.

The population of heterotrophic bacteria, hydrocarbon degrading bacteria and fungal species in soil samples collected from the spill site ranged from 4.20 x 10^5 - 1.30 x 10^6

cfu/ml; 8.00 x 10^2 - 1.60^3 cfu/ml; and 3.50 x 10^2 - 1.60 x 10^3cfu/ml respectively. It was observed that the hydrocarbon utilizing bacterial species constituted about half the total population of heterotrophic bacteria in the samples.

A comparative analysis of the physico – chemical characteristics of soil samples using the soil characteristics at the control station as benchmark is presented in Table 2.0. From this Table, the characteristics of surface soil within the spill site and at the control station are in general consistent. The exception is the THC content that was much higher within the spill site. The THC content of soil within the spill area was also significantly higher that the DPR recommended limits of 50mg/kg (FEPA, 1991; DPR, 1991).

3.1.3 Wildlife

The status of wildlife (mammalian, avian and reptilian fauna) within and around the Etiama spill site was assessed through interviews with hunters and trappers in communities within the area. It was established that common wildlife species inhabiting the rainforest portion of the area include antelope, baboon, monkey, reptiles, birds, rodent and turtle.

Some of the persons interviewed claimed that at least two pythons, numerous turtles and a variety of other wildlife were destroyed by the fire incident of 20th May 2000. It was not possible to substantiate these claims and no significant changes in the abundance and/or diversity of wildlife species within and around the spill sites were reported.

3.2 Aquatic Ecology

3.2.1 Surface Water

The status of surface water within the Etiama oil spill was determined through sampling and testing for key physico-chemical and biological parameters including the total hydrocarbon (THC and poly-aromatic hydrocarbon (PAH) contents of water.

Eleven (11) composite samples (each composite samples consists of mixture of one bottom and one surface) were collected from the various creeks affected by the spill. A control sample was collected from a station located about 30km away from the spill site.

The pH of surface water within the spill site ranged between 6.54 and 6.84 with an average of 6.72. The pH of the control sample was 6.8. The conductivity of surface water ranged between 66.4 and 328μS/cm. The salinity of surface within the spill site ranged between 0.00–0.2ppt with an average of 0.8ppt. The salinity of the control sample was 1.10ppt. The redox potential of surface water within the spill site ranged between 241–

282mV with an average of 258.2mV. The redox potential control water sample was 260mV.

Table 2.0 Comparative Analysis of Key Physico-chemical Characteristics of Soil in Spill Area.

S/No	Parameters	Average Value in Spill Area	Value at Control Station.
1.	PH	5.36	6.89
2.	Conductivity	211.4μS/cm	1294.0μS/cm
3.	Salinity	0.11ppt	0.6ppt
4.	Redox Potential	75.0mV	97.0mV
5.	Calcium	298.1mg/kg	552.0mg/kg
6.	Potassium	695.1mg/kg	1456.0mg/kg
7.	Magnesium	1327.1mg/kg	808.0mg/kg
8.	Sodium	65.3mg/kg	67.0mg/kg
9.	Nitrate	6.82mg/kg	7.8 mg/kg
10.	Phosphate	12.83mg/kg	19.6mg/kg
11.	Sulphate	142.5mg/kg	325.0mg/kg
12.	Copper	6.67mg/kg	7.00mg/kg
13.	Lead	38.2mg/kg	74.00mg/kg
14.	Nickel	25.6mg/kg	<0.10mg/kg
15.	Cadmium	1.4mg/kg	<0.20mg/kg
16.	Arsenic	0.94mg/kg	0.35mg/kg
17.	Mercury	0.11mg/kg	0.08mg/kg
18.	Barium	22.0mg/kg	<0.03mg/kg
19.	Iron	9552.6mg/kg	12261.00mg/kg
20.	THC	1358.5mg/kg	172.00 mg/kg

(Source: PFL, 2001)

The nutrient (Calcium, Potassium, Magnesium, Sodium, Nitrate, Phosphate and Sulphate) contents of surface water within the spill site ranged between 1.16 – 1.86mg/l, 1.07 – 1.82mg/l, 1.12 – 3.22mg/l, 3.74 – 21.7mg/l, 0.72 –0.78mg/l, 1.24 –2.42mg/l and 1.72 – 12.7mg/l respectively. The average nutrient contents of surface water were 1.4mg/l, 1.36mg/l, 1.76mg/l, 9.39mg/l, 0.75mg/l, 1.62mg/l and 5.0mg/l respectively.

The total suspended solids (TSS) and total dissolved solids (TDS) levels in surface water within the spill site ranged from 38 – 74mg/l and 31 – 157mg/l respectively. The average TSS level was 56.6mg/l while the average TDS level was 71.6mg/l. The biological oxygen demand (BOD) and chemical oxygen demand (COD) levels in surface water

ranged from <1.0 – 53.3mg/l and <4.0 – 80mg/l with averages of 35.8mg/l and 53.9mg/l respectively.

The heavy metal (Copper and Iron) content of surface water within the spill site ranged between <0.05 – 0.126mg/l and 1.29 – 3.53mg/l respectively. The average concentrations of these heavy metals in the surface water were 0.08mg/l and 1.53mg/l respectively. Lead, Nickel, Cadmium, Arsenic, Mercury and Barium were not detected in the surface water samples. Total hydrocarbon (THC) was not detected in any of the samples.

The microbial species identified in surface water within the spill site included *Micrococcus, Klebsiella, Escherichia, Pseudomonas, Bacillus, Staphylococcus, Mucor,*

Rhizopus and Asperigillus. These were classified as heterotrophic bacteria, hydrocarbon utilizing bacteria and fungi.

The population of heterotrophic bacteria, hydrocarbon degrading bacteria and fungal species in surface water samples collected from the spill site ranged from 9.45×10^4 cfu/ml – 5.4×10^4cfu/ml; 1.18×10^2cfu/ml – 9.1×10^2cfu/ml; and 7.0×10^1 – 4.75×10^2 cfu/ml respectively. From the result, hydrocarbon utilizing bacteria species population constitutes about half the total population of heterotrophic bacteria in the samples. This high ratio of hydrocarbonoclastic microbial population to total heterotrophic microbial populations indicates previous significant hydrocarbon input into the soil.

The phytoplankton population in surface water within the spill site comprised of sixteen (16) species of *Bacillariophyceae*, three (3) species of *Chlorophyceae* and four (4) species of *Cyanophyceae*.

A comparative analysis of key physico – chemical characteristics of surface water in the spill area and at the control station is presented in Table 3.0. This table suggests that there are dissimilarities in the physico – chemical characteristics of surface water within the spill area and at the control station notably with respect to conductivity, total dissolved solids, calcium, magnesium, sodium and sulphate. The observed differences may be due to the natural changes in the characteristic of inland waters as they approach the ocean and the influence of the marine water increases.

It was noted that THC and PAH were not detected in the water samples. However, the relatively high occurrence of hydrocarbon utilizing bacteria indicates the presence of hydrocarbon in the area.

3.2.2 Sediment

The status of surficial sediment beneath the creeks within the Etiama oil spill site was determined through sampling and testing for key physico – chemical and biological parameters. A total of ten (10) sediments samples, including the control sample, were collected and analyzed.

The pH of sediment within the spill site ranged between 5.88 and 6.83 with an average of 6.32. The pH of the control sample was 6.59. The conductivity, salinity and redox potential of sediments in the spill site ranged from 123 to 740μS/cm, 0.1 to 0.4ppt and 158 to 38mV with averages of 392μS/cm, 0.2ppt and 116mV respectively.

The nutrient (Calcium, Potassium, Magnesium. Sodium. Nitrate, Phosphate and Sulphate) contents of sediment within the spill site ranged from 111 – 1162mg/kg, 191 – 1365mg/kg, 90 – 1928mg/kg, 51 – 1904mg/kg. 4.86 – 7.33mg/kg8.4 – 21.7mg/kg and 100 – 675mg/kg respectively. The average nutrients content in the sediment were 521.9mg/kg, 873.6mg/kg, 1235.7mg/kg, 383.2mg/kg. 6.1mg/kg, 12.3mg/kg and 291.7mg/kg respectively.

The heavy metal (Copper, Lead, Nickel, Cadmium. Arsenic, Mercury, Barium and Iron) content of surficial sediment within the spill site ranged from <0.05 – 16.0mg/kg, <4 – 81mg/kg, <0.1 – 24mg/kg, <0.02 – 3.0mg/kg. <0.001 – 1.01mg/kg, <0.0002– 0.16mg/kg, 5.0 – 33.0mg/kg and 2942 – 26505mg/kg respectively. The average concentration of these metals in sediment samples was 11.38mg/kg. 9.5mg/kg, 1.75mg/kg, 0.79mg/kg, 0.12mg/kg, 19.7mg/kg and 13083.56mg/kg respectively.

Table 3.0 Comparative Analysis of Key Physico – Chemical Characteristics of Surface Water Spill Area.

S/No	Parameter	Average Value of Spill Area	Value of Control Station
1.	pH	6.72	6.8
2.	Conductivity	148.4μS/cm	2220.0μS/cm
3.	Salinity	0.08ppt	1.10ppt
4.	Redox Potential	258.2mV	260mV
5.	TSS	56.6mg/l	98.0mg/l
6.	TDS	71.6mg/l	1110.0mg/l
7.	BOD	35.8mg/l	41.7mg/l
8.	COD	53.9mg/l	63.0mg/l
9.	Calcium	1.4mg/l	13.7mg/l
10.	Potassium	1.36mg/l	18.5mg/l
11.	Magnesium	1.76mg/l	56.5mg/l
12.	Sodium	9.39mg/l	361.0mg/l
13.	Nitrate	0.75mg/l	0.68mg/l
14.	Phosphate	1.62mg/l	1.28mg/l
15.	Sulphate	5.0mg/l	160mg/l
16.	Copper	0.08mg/l	<0.05mg/l
17.	Lead	<0.20mg/l	<0.25mg/l
18.	Nickel	<0.10mg/l	<0.10mg/l
19.	Cadmium	<0.02mg/l	<0.02mg/l
20.	Arsenic	<0.001mg/l	<0.001mg/l
21.	Mercury	<0.0002mg/l	<0.0002mg/l
22.	Barium	<0.03mg/l	0.36mg/l
23.	Iron	1.53mg/l	<0.05mg/l
24.	THC	<1.00mg/l	<1.00mg/l

(Source: PFL, 2001)

The total hydrocarbon (THC) content in samples ranged from 29.2 – 19434mg/kg with average of 4596.1mg/kg. Polyaromatic hydrocarbon (PAH) was only detected at one sampling station at a concentration of 80.3mg/kg. The population of heterotrophic bacteria, hydrocarbon degrading bacteria and fungal species in surficial sediment samples collected from the spill site ranged from 7.0 x 10^4 – 9.2 x 10^5cfu/ml; 2.5 x 10^2 – 1.35 x 10^3 cfu/ml respectively.

Table 4.0 presents a comparative analysis of key physico – chemical characteristics of sediment in the spill area and at the control station.

The slight dissimilarities that may be observed with respect to some physico-chemical parameters of the sediment samples from the spill area and from the control station may be attributed to natural changes that are expected to occur in the characteristics of inland rivers as they approach the ocean. The relatively high THC content of sediment from the spill area (compared to the concentration at the control station) is apparently due to the oil spill incident.

Table 4.0 Comparative Analyses of Key Physico-Chemical Characteristics of Sediment in Spill Area.

S/No	Parameter	Average Value of Spill Area	Value of Control Station
1.	PH	6.32	6.59
2.	Conductivity	392.0µS/cm	1837.0µS/cm
3.	Salinity	0.2ppt	0.90ppt
4.	Redox Potential	116.0mV	74.0mV
5.	Calcium	521.9mg/kg	139.0mg/kg
6.	Potassium	873.6mg/kg	1703.0mg/kg
7.	Magnesium	1235.7mg/kg	1602.0mg/kg
8.	Sodium	383.2mg/kg	226.0mg/kg
9.	Nitrate	6.1mg/kg	6.34mg/kg
10.	Phosphate	12.3mg/kg	14.4mg/kg
11.	Sulphate	291.7mg/kg	125.0mg/kg
12.	Copper	11.38mg/kg	<6.00mg/kg
13.	Lead	57.40mg/kg	39.0mg/kg
14.	Nickel	9.50mg/kg	10.0mg/kg
15.	Cadmium	1.75mg/kg	<0.02mg/kg
16.	Arsenic	0.79mg/kg	0.18mg/kg
17.	Mercury	0.12mg/kg	0.12mg/kg
18.	Barium	19.7mg/kg	<0.03mg/kg
19.	Iron	13083.56mg/kg	10719.0mg/kg
20.	THC	4596.10mg/kg	108mg/kg

(Source: PFL, 2001)

3.2.3 Benthic Organisms

The status of benthic organisms within the Etiama oil spill site was studied through sampling and laboratory analysis and visual observation. Two (2) species each of *Crustaceans* and *Molluscans* and one species of *Pisces* were identified within the spill site. The most populous species of benthic organisms in the spill area were *Molluscans* (51.02%) and closely followed by *Crustaceans* (34.69%). The percentage population of *Pisces* in the spill site was 14.28.

3.2.4 Fisheries

The numerous small creeks and creeklets that characterize the spill area are a major breeding/spawning ground for diverse fish species. Thus in the spawning season (rainy season) the diversity and abundance of fisheries in the spill area is expected to be very high as the fishes move away from the sea and larger water bodies with high wave energy

contents into these quiet and serene areas to spawn and breed. Major groups of fishery resources that have been observed from fishermen catches in the area are listed in Table 5.0 below.

Table 5.0 Major Groups of Fishery Resources From Fishermen Catches in Etiama.

Common Name	Scientific Name
Sardine	*Sardinella* spp.
Mullets	*Muggil* spp.
Croaker	*Pseudololithus* spp.
Snapper	*Latjamus* spp.
Barracuda	*Sphyraena* spp.
Swim Crab	*Callinectes* spp.
Fidder Crab	*Uca tangeri*
Mangrove Crab	*Uca tangeri*
Crayfish	*Nematocarcins* spp
Shrimp	*Penaeus* spp.
Mangrove Oysters	*Crassostrea* spp.
Periwinkles	*Tympanotmus* spp.

(Source: PFL, 2001)

The existence of these species in the spill area has been confirmed by previous studies (Ecosphere Nigeria Limited, 1997; Federal Department of Fisheries, 1980).

The status of fish within the spill site was studied through interview of local fishermen, visual inspection of fish catch and laboratory analysis of some fish samples. The concentrations of PAH in tissue of fish and crayfish (from Agbakabiriya Creek) were 218mg/kg and 13.1mg/kg respectively. Furthermore, the concentrations of TPH in fish and crayfish tissues (from Agbakabiriya Creek) were 9715mg/kg and 5866mg/kg.

3.2.5 Ground Water Characteristics

Groundwater samples were collected from two boreholes (BH1 and BH2) drilled within the spill site. In general, the physico-chemical and biological characteristics of the groundwater samples were consistent with geology and hydrogeology of the area.

3.3 Socio – Economic Aspects.

The socio-economic aspects of the Etiama oil spill were discussed in details in the Initial Environmenal Assessment Report (PFL, 2001). The key socio-economic aspects of the Etiama oil spill on Ewokiri, Igbeta-Ewoama, Etiama, Agbakabiriya, Ebikiri, Kalkukumbug, Ijawkiri and Edwinikiri are discussed below.

It was estimated in the initial environmental assessment report that total fish, crayfish and shellfish catch/effort (kg/day), within the spill area, were 5472, 4104 and 9576 respectively.

The estimated sizes of plantain, cassava, pineapple, rubber and sugarcane farms/plantations within the spill area were 23.5, 31, 3, 15 and 11 acres respectively. Rice farms were not sighted in the spill area even though all the communities claimed to own several acres. Fishponds were found in all villages.

It was also cited in the initial environmental assessment report (PRODEC-FUGRO Ltd; 2001) that some lives were lost during the fire incident of 20th May 2000 at the spill site. The exact number of lives is not confirmed. However, interview with the community members confirmed that the deceased were from Etiama and Agbakabiriya villages.

4.0 Significant Environmental Impacts of Etiama Oil Spill

4.1 Impacts on Terrestrial Ecology

4.1.1 Impacts on Vegetation

It is estimated that about 15 square kilometers of mangrove vegetation has been destroyed by the Etiama oil spill. The portions of the mangrove forest that were most heavily impacted are on the banks of Osuma and Agbakabiriya Creeks.

The death of the mangrove plants must have been as a result of the oiling of their breathing roots after the spill. The plant tissue analysis results also indicate that the spill may have adversely affected the nutrient uptake capability of the plants. The impact of the Etiama oil spill on mangrove vegetation is considered significant because it typically takes decades for mangrove ecosystem to return to status quo once perturbed.

The rainforest within the spill area was minimally impacted by the oil spill. The rainforest area (along the pipeline ROW) burnt by the fire of 20/05/2000 has nearly returned to its status quo but the $15km^2$ mangrove vegetation is to be re – vegetated.

4.1.2 Impacts on Soil

The soil analysis results suggest that surface soil within the spill site is contaminated with hydrocarbon above the DPR recommended limit of 50mg/kg. Soil in the spill area generally peaty. Hence it is believed that tidal flushing will reduce the hydrocarbon concentrations to acceptable limits with time.

4.1.3 Impacts on Wildlife

The majority of the wildlife to be found within the spill area are to be found in the rainforest and this was only affected by the fire of 20/05/2000. Thus, the only significant impact of the spill/fire incident is in relation with the incineration of the animals listed in chapter three. Furthermore, the rainforest is nearly fully restored and the issue of undue exposure of wildlife to poaching and other hazards is not considered significant.

4.2 Impacts of Aquatic Ecology

4.2.1 Impacts on Surface Water

Generally, the water samples analysis results do not suggest that surface water within the spill area is contaminated by hydrocarbon. Furthermore, no visible oil sheen was observed on the water surface as at the time fieldwork for the PIA was conducted.

4.2.2 Impacts of Sediment

The sediment analysis results indicate that sediment material within the spill area is contaminated with hydrocarbon. In addition it was observed during fieldwork that oil sheen appears on the water surface once the sediment layer is disturbed. This supports the laboratory results.

4.2.3 Impacts on Benthic Organisms

The unusually high concentration of hydrocarbon in the sediment layer within the spill area (including the periodically exposed tidal mudflats) has adversely affected benthic organisms in the area. In some sheltered areas such as Agbakabiriya Creek, whole communities of periwinkles and other benthic organisms were destroyed by the oil spill. The oil still persists in such areas and the communities of socio-economically valuable organisms are not likely to be re-established in such areas for quite some years.

4.2.4 Impacts on Fisheries

The impacts of the Etiama oil spill on fisheries were immediate, relatively short-lived and significant. The villagers report that thousand of fish died and floated on the water surface within one week of occurrence of the spill. The report could be an exaggeration.

The status of fisheries, particularly catch and yield is not expected to return to normal within the next couple of years because of the contaminated sediment layer since most of the fish depend on the primary producers that in turn depend on the sediment layer for supply of nutrients.

4.2.5 Impact on Groundwater

The analysis results do not suggest that groundwater within the spill area has been contaminated with hydrocarbon. However, the possibility fir this to occur will remain if oil recovery pits are not properly cleaned and closed-out.

4.3 Impact on Socio-Economics

The Etiama oil spill indirectly and adversely impacted on the socio-economic well being of the communities in the spill area. The reduced fisheries catch and yield impacted adversely on the income of the people who are mostly fishermen. Furthermore, the owners of the contaminated fishponds in Agbakabiriya village may have lost a significant investment as a result of the incident.

The destruction of edible benthic organisms such as periwinkles and shellfish also impacted adversely on the income and diet of the communities and therefore the health of the residents.

Perhaps the most critical of the socio-economic impacts of the Etiama oil spill of the area is associated with the loss of lives as a result of the fire incident.

5.0 Baseline Status of Etiama Oil Spill Site After Two Years

This section therefore highlights the environmental status of the Etiama oil spill site as at 6th – 10th May, 2002, about two years after the oil spill.

As a first step towards the environmental rehabilitation of the affected area, a pre-mangrove vegetation study vis-à-vis a baseline study was carried out through the collection of essential data.

Environmental base-line data collection for the provision of the necessary chemical and biological data was carried out with a view to obtaining qualitative and quantitative information on the present state of the environment within the Etiama study area and other adjoining creeks.

Such studies and data collection will lead to the establishment of comprehensive baseline data on the existing state of all identifiable ecosystems around the areas of operational interest against which a long term monitoring programme can be planned and implemented.

5.1 The Etiama Oil-Spill Site Study Area and the Adjoining Environment.

The Etiama oil-spill site and the adjoining environment is dominated by two types of Ecosystems, namely:

1. The Terrestrial Ecosystem made up of the mangrove swamp forest ecotypes and
2. The Aquatic Ecosystem (Brackish Water)

It should be noted that the swamp forest is a collective term used for forests, which are regularly flooded or have waterlogged soils. They have biological species composition different from that in typical lowland rain forest.

Lots of swamps abound. Extensive mangrove creek networks characterize the area with tall mangroves at the creek edges while further inland short mangroves are the only mangroves growing. This has become the situation because the Mangroves Zone are also divisible into two: First is the soft mud of silt and clay that carries tall mangroves – *Rhizophora racemosa*. These soils have high silt and clay with a range of 40% - 97%, the reminder being fine sand. The colour is black to dark grey.

The vegetation of the tidal flats consists of *Rhizophora racemosa, Rhizophora mangle, Rhizophora harrisonii, Avicennia africana, Larguncularia racemosa* and the fern *Acrostichum aureum.*

The greater part of the mangrove vegetation is formed by *Rhizophora racemosa,* Dense stands of this species, reaching 30 – 45 metres in height grow at the extreme edges of the point bars formed in the Meander loops of open ended creeks in which the area abounds. The height of the mangroves decreases from the foreshore to the interior of the bars.

Relatively tall *Rhizophora racemosa* trees of uniform height (15 – 20 metres) line both banks of the blind channels, which drain the interiors of the tidal flats. The interiors of the tidal flats are covered by a rather open stand of mainly low (5 meters) *Rhizophora racemosa* shrubs.

Avicennia africana, Laguncularia racemosa and Acrostichum aureum occur on the somewhat higher lying spots of the tidal flat area.

5.2 Wildlife Resources of Etiama Oil Spill Site and Environs

Investigations on the wildlife resources of Etiama and environs have been few; the most recent wildlife data are due to Powell (1995) and CORDEC (1996). Analysis of the data reveals that the wildlife comprises a considerable number of species of conservation interest. Among them are, bovids, primates, lesser primates, birds and members of the cat family.

Besides, the fauna diversity, which characterizes mangrove swamp forest as those of Etiama has elaborately been discussed (Bossi and Cintron, 1990; Powell 1995, Akani, et al 1999). Mangrove swamp forests constitute very important nurseries or breeding grounds for many species of finfish and shell fish (Bossi and Cintron 1990). The maze of interlaced roots offers fish larvae and fingerlings abundant food, and protection against larger predators. These prop roots also provide the hard substrate required for attachment of sessile marine lives (Tait, 1975) such as oysters, barnacles, hydroids, tunicates, and bryozoans. The swamp is invariably a repository of rich detritus for the marine food web, and the prop roots of mangroves in particular often develop rich communities of macro-algae and invertebrates (Tait, 1975).

It is also well known that sandy shorelines of mangrove and freshwater swamps provide spawning grounds for amphibious reptiles, like - Crocodiles, Nile monitors and turtles (Branch, 1988), and mammals like River Otter (Kingdon, 1997). Working on sites and species of conservation interest in the Central Niger Delta, Powell (1993) noted that the zone south of Yenagoa of which Etiama is part, holds a considerable diversity of chelonians, and these are common in remote areas (NDES, 1998). Among the chelonian fauna identified were four sea turtles, one river turtle and two land tortoises namely: the loggerhead. ***Caretta, caretta;*** **Green** turtle. ***Chelonia mydas;*** Hawksbill turtle, ***Eretmochlys imbricata;*** Olive Ridley, ***Lepidocheys olivacea;*** Softshell or River Tortoise, ***Kinixys erosa*** and Home's Hinge back Tortoise, ***Kinixys homeana.***

The avifauna assemblage of mangrove swamps of the Niger is also diverse (Politano, 1997) as birds find the habitat rich in food resources, and highly suitable for perching and nesting. The bulk of them are waders and swimmers with appropriate adaptive beaks and talons to utilize the variety of food available along shoreline. Among them are insect gleaners, piscivores, honey feeders, snail eaters, divers and mud-sievers (Bossi and Cintron 1990; Elgood et al, 1994).

Rain forest wildlife species generally exhibit differences in time of activity (Hopkin 1974); while some are active by day, others rest by day and become active by night. Mammals in particular belong to the latter category, and are very secretive by day. For this reason most mammals are not readily seen during the day, and the forests appear as though they are devoid of mammalian life.

The economic importance of wildlife species has elaborately been discussed (Dasmann, 1964; NARESCON, 1992, 1993). The benefits vary from locality to locality and could be of commercial value as tasty meat, leather for drums, materials for traditional medicine, decorations or souvenirs.

Various agencies and authorities in wildlife conservation have in recent times drawn attention to the rapidly depleting biodiversity of tropical rain forests (Fagbemi et al. 1988; NARESCON, 1992, Common and Norton, 1992: World Bank 1995, 2000, 2001). They trace the proximate sources of wildlife depletion to: (i) habitat destruction and alteration, and (ii) indiscriminate or uncontrolled hunting.

In some cases habitat destruction and modification are deliberate and tied to major development projects such as road construction, reclamation, construction of airport, industrial and housing estates, agriculture. etc. In other cases, habitat destruction / modification is indirect and unintended as with consequences of pastoralism, lumbering, pollution and introduced (or exotic) species. Hunting is also implicated because it remains an important source of income for many rural households and often operates under an open-access regime. On the whole, it is now well established that habitat destruction has a far more devastating effect than do hunting. Consequently, the major conservation strategy in practice today, is the prudent management of wildlife habitats (Fagbemi et al, 1988; World Bank, 2000).

The wildlife inventory of Etiama and environs indicates the presence of about 61 species. There are 20 mammalian species from 10 families; 22 avian species from 13 families; 17 reptilians' species from 10 families and 2 amphibian species from 2 families. Observations on the wildlife here reveal that the bulk of the animals reside in the "slands" of lowland rain forests from where they migrate to the shorelines to fish during low tide – e.g shoreline birds, Crocodiles, Nile monitors, Water turtles, etc. More footprints and vocalizations were noted in parts of the transects farther away from the oil spill site, than the oiled site proper., which suggests that the wildlife are presently avoiding the heavily impacted area by habituation – a phenomenon which was also observed by CORDEC (1996).

5.3 Vegetation Distribution after the oil spill.

A major oil spillage occurred in the Etiama area and affected two Ecosystems, namely: (1) Aquatic Ecosystem (2) Terrestrial Ecosystem.

Extensive mangrove creek networks, which are open ended, characterize the area and because of this, the spilled oil on the water surface in the creeks easily flowed into the larger water bodies and was easily dispersed within the aquatic system. In the case of Terrestrial Ecosystem the spilled oil flowed into land areas and settled within the habitat causing extensive and enormous damage to the plant life. This can be seen from the large areas carrying dead and tall standing red mangrove plants and other plant species like the umbrella trees or cork wood, Teak plants and wild date palms.

These findings indicate that the structure and floristic composition of the present vegetation types in the affected Etiama area have resulted from the enormous habitat disturbance of the original mangrove forest vegetation.

Experience with vegetation studies in general, indicates that the observed characteristics are continually changing with changes in soil and habitat history of the area. So there is need for some reassessment from the time to time in order to fully appreciate the entire ecological trends around the locations in the study area.

The swamp forest ecosystem is based predominantly in plant litter (leaves, fruits) and insects, falling unto the water from the surrounding forest. If the forest is cleared or the plants die exposing the swamp to light, considerable primary production occurs within the water, which changes the base of the food chain, but the fish fauna remains roughly the same. This is because the controlling factor is not the food types but rather the ability to survive the dry season.

The terrestrial ecosystem is made up mainly of mangrove swamp forest as the dominant type of vegetation – primarily because mangroves are the emergent land plants that can tolorate the salinities of the oceanic waters and coastal creeks. Keay (1959) has reported that the mangrove vegetation in West Africa comprised of *Rhizophora mangle, Rhizophora racemosa and Rhizophora harrisonii* and that associated with these species are *Pandanus* species and the fern *Acrostichum aureum.*

Within the extensive mangrove creek networks are found tall mangroves at the creek edges while further inland short mangroves are the only mangroves growing. Two soil types are recognizable within the mangrove zone.

First is the soft mud of silt and clay that carries tall mangroves – *Rhizophora racemosa.* On the death of the tall mangroves the roots remain in the soil, accumulating as organic matter. A few generations of this process converts the soil into peaty clay or "Chikoko" which is the second type of soil.
The "Chikoko" can no longer support the tall mangroves trees of *Rhizophora racemosa:* and the successors are stunted species of *Rhizophora nangle and Rhizophora harrisonii.* The fern, *Acrostichum aureum* growing in clumps is found growing among these mangrove species. *Avicennia africana, Laguncularia racemosa* and the fern *Acrostichum aureum* occur on the somewhat higher lying spots of the tidal flat area.
The rain forest is the other type of Terrestrial Ecosystem found within the Etiama study area. The forest is fully mature with trees well differentiated into three distinct strata characteristic of tropical lowland rain forest.

There are fringes of transitional woodland type of vegetation found on the old dredge spoils, which represent in part patterns of stages in succession to a climax vegetation. This is the picture that has emerged about the pattern of the distribution of the vegetation in the area not affected by spillage under study at this point in time. The structure and

distribution of vegetation within the various transects/locations remains basically the same.

It is recommended that species that are estimated with over 50% in frequency of distribution in the study area should be regarded as the most successful and abundant and therefore dominant of the stage in the succession to climax in any of the given transects/locations.

Apart from the soft mud of silt and clay and the hard "Chikoko" soils supporting mangroves of different formations/heights as indicated above, the species in the areas not affected by the oil spill were distributed in a random manner and no other spatial pattern of distribution was discernible even down transect.

5.4 Soil Quality

The range and mean values for the various parameters measured in the soil samples at the two depths sampled are presented in Table 6.0

Particle Size

The textural classification of the samples collected from the Osuma transect ranged from loamy sand to silt loam, while the pipeline transect soils were silty clay loam at both depths.

Soil pH

The pH of these soils was acidic. Most of the samples fell within the pH range of 3.7 - 5.7 with a mean of 5.16 at the surface and 3.9-6.4 (mean-5.04) at the subsurface and classified as strongly to moderately acid. This is typical of acid peat soils and the implication is, among others, that it may cause a build-up of manganous and ferrous ions, which in turn may impose adverse effect to soil flora and fauna.

Electrical conductivity (E.C.)

The E.C. values are given in the appendix and corroborate the available data on pH. Topsoil values ranged from 2,320-63,630 uS/cm (mean – 6,363) while that of the subsoil ranged from 740-9260uS with a mean of 6,076. Apart from at station ET 1 where the E.C. of surface soil was significantly different from the subsurface soils (i.e. 2,320 and 740uS/cm respectively), the rest did not show any remarkable difference. The general observation is evidence that the soils are saline. This can cause enlarged stress to flora and fauna and a decline of the inert capacity of the soil to recover from oil spill.

Organic Carbon /Total Nitrogen

Ranges of Organic carbon (OC) of 3.32% - 5.72%(mean = 5.13) and 1.46% - 5.96% (mean = 4.81) were obtained for the surface and sub soils respectively. These levels are high but are much lower than those measured in similar ecosystem (IPS 1991). In several mangrove ecosystems the continuous deposition of litter gradually forms a mat layer reach in organic carbon. This however is not the case here as this environment has shown signs of stress probably caused by the scorching of the area following an oil spill several months earlier.

Nitrogen is the most important nutrient element for plants and ranged from 0.18% - 0.48%, with a mean of 0.38% and 0.1% - 0.48% (mean = 0.36) respectively for surface and sub-soils. There was no particular trend observed with depth neither were the differences significant. With abundant microbial population and adequate levels of phosphorous, these nitrogen levels will sustain growth of several native biotic species. Total N correlated with OC indicating that the reserve of this element is mostly from organic matter (Okusami, 1986; Nelson and Sommers, 1992; Bremner and Mulvaney, 1982).

Sulphate

The Sulphate levels were moderate and did not vary remarkably with transects. Topsoil levels ranged from 25.65 – 45.86mg/kg (mean = 35.72) while the subsoil range was from 15.25 – 58.52mg/kg with a mean of 36.71.The Sulphate characteristics of these soils could have been acquired from the hydrolysis of the readily available hydrogen Sulphide and contributed to their acid-sulphate nature. The levels are however adequate for normal growth of indigenous flora and fauna.

Ammonium and Nitrates

Mineralization of nitrogen appears not to be inhibited as the mean levels of mineral nitrogen show at the top and sub soils respectively – (NH_4^+ = 89.46 & 85.73mg/kg; NO_3^- = 23.67 & 24.19mg/kg). This result indicates that there was a transformation of organic matter into NH_4^+-N and NO_3-N, which normally occurs through the action of nitrifying bacteria.

Total hydrocarbon (THC)

The concentrations of THC in the soils of polluted area were varied. The level ranged between 233.39 – 14,747.26 ppm for surface soil and 192.8 – 26,014.05 at the subsoil (Table 6.0). The levels for most of the samples collected along the pipeline transect decreased with depth probably as a result of increasing level of biodegradation down the soil profile. The levels along the Osuma creek transect did not follow any particular trend. The concentrations in station ET1 were unusually high at both depths (14,747.26

and 15,694.34ppm respectively). This suggests additional THC contamination possibly from boats used by the recently deployed field workers since station ET 1 is the mustering points for personnel as well as their boats. The concentration of biogenic hydrocarbon (CONCAWE, 1972) has been put at 50.0ppm. The values measured here are far in excess of this level. The previously spilt crude oil in this soil environment is evidently implicated for the elevated THC levels measured although they are at various stages of degradation.

Heavy Metals

Results of heavy metals are given in the appendix and indicate relatively low levels of the metals measured. Whereas vanadium (V) was not detected in any of the stations, the concentration of nickel (Ni) in the soil column ranged from 0.65 – 2.23ppm and 0.53 – 2.20ppm in the top and subsoil respectively. The values obtained here are within normal averages for mangrove ecosystems (Odu, 1989) and do not indicate pollution.

The soil study shows a healthy condition of the soils except, perhaps, the elevated total hydrocarbon levels in a few stations. The frequent flushing of the area due to tidal influence may have enhanced the level of recovery.

5.5 Microbiological Status Etiama Oil Spill Site

The microbial counts and species diversity of water / sediments samples from Etiama oil field sites are presented in Table 7.0 below.

The total heterotrophic bacteria counts of the water samples from the study site were high and ranged from 1.6x 10^5 to 6.5 x 10^5 cfu/ml. The microbial densities are generally higher at the surface water than at the subsurface water level. The total density of total heterotrophic bacteria in the surface water is about five times higher than that at the subsurface level. The ratio of hydrocarbon utilizing bacteria to the total heterotrophic bacteria is generally high 6.2 x 10^4 – 3.6 x 10^4 cfu/ml to 6.5 x 10^4 – 1.6 x 10^5 cfu/ml. The density of coliform bacteria is very low and indeed coliforms are detected in only few of the samples.

The predominant bacteria genera isolated from the water samples in the study area include *Bacillus sp. Pseudomonas sp. Trichoderma sp. Desulfovibrio sp. Acremonium sp. Achromobacter sp. Flavobacterium sp. Micrococcus sp. Aeromonas sp and Sphingomonas sp.*

Table 6.0: Range and Mean Physico-chemistry/Total Hydrocarbon/Metals of Etiama Oil Spilt Site Soils at Two Depths

No	Parameters	0 –15cm		15 – 30cm	
		Range	Mean	Range	Mean
1	PH	3.7-5.7	5.16	3.9-6.4	5.04
2	Electrical conductivity (uS/cm)	2,320-63,630	6.363	740-9,260	6,076
3	Organic carbon (%)	3.32-5.72	5.13	1.46-5.96	4.81
4	Total nitrogen (%)	0.18-0.48	0.38	0.1-0.48	0.36
5	Sulphate (SO_4^{2-}) mg/kg	25.65-45.86	35.72	15.25-58.52	36.71
6	Ammonia (NH_4^+) mg/kg	58.48-112.72	89.46	62.25-120.28	85.73
7	Nitrate (NO_3^-) mg/kg	12.52-36.18	23.67	12.68-32.68	24.19
8	Total hydrocarbon (THC) mg/kg	233.39-4747.26	3.907.35	192.8-26.014.05	2601.41
9	Nickel (Ni) mg/kg	0.65 – 2.23	1.42	0.53 – 2.20	1.24
10	Vanadium (V) mg/kg	< 0.001	<0.001	<0.001	<0.001

(Source: Envir-Health, 2002)

The occurrence and distribution of bacterial isolates recorded are indicated in Table 7.0.Their occurrence are higher at the Osuma Creek water than the pipeline transects. This may be due to sequential biodegradation by members of the genus *Bacillus* and *Pseudomonas*. Members of this group are well known for their wide occurrence in oil-polluted sites and their ability to use a wide range of substrates. The generally high ratio of hydrocarbon utilizing bacteria suggests that the environment is highly polluted with oil (Atlas and Bartha, 1998; Udotong, 2000).

Total heterotrophic fungi counts ranged from 1.1 x 10^5cfu/ml – 2.5 x 10^5 cfu/ml. The predominant fungi genera isolated from the water samples include *Alternana sp, Fusaruim sp, penincillum sp, Aspergillus sp, Rhizopus sp, Mucor sp, Acremonium sp, Chalaropsis sp and collentroticum sp*.

Table 7.0 Microbial Counts of Water Samples from the Study Area.

Sample location	Total heterotrophic bacteria count	Total fungal count	Hydrocarbon utilising Bacteria (HUB)
Et 1	6.5 x 10^5	4.6 x 10^5	6.2 x 10^5
2	2.18 x 10^5	1.9 x 10^5	4.3 x 10^5
3	4.3 x 10^5	2.2 x 10^5	3.6 x 10^5
4	5.6 x 10^5	2.5 x 10^5	4.3 x 10^5
5	5.9 x 10^5	2.3 x 10^5	6.6 x 10^5
6	6.1 x 10^4	2.3 x 10^5	5.1 x 10^5
7	4.6 x 10^5	1.2 x 10^5	4.5 x 10^5
8	3.4 x 10^4	1.1 x 10^5	3.9 x 10^5
9	2.1 x 10^5	1.2 x 10^5	5.2 x 10^5
10	1.6 x 10^5	1.6 x 10^5	4.4 x 10^5

(Source: Envir-Health, 2002)

Table 8.0: Microbial Counts of Sediments Samples from the Study Area

Sample location	Total heterotrophic bacteria count	Total fungal count	Hydrocarbon Utilising Bacteria (HUB)
ET 1	8.1 x 10^5	4.3 x 10^5	7.1 x 10^5
2	3.7 x 10^5	1.2 x 10^5	3.6 x 10^5
3	3.9 x 10^5	1.2 x 10^5	4.2 x 10^5
4	4.6 x 10^5	1.2 x 10^5	3.5 x 10^4
5	4.2 x 10^4	1.2 x 10^5	5.1 x 10^4
6	4.9 x 10^5	2.2 x 10^5	5.6 x 10^5
7	6.2 x 10^5	2.10 x 10^5	6.6 x 10^4
8	5.1 x 10^5	1.6 x 10^5	5.6 x 10^4
9	4.2 x 10^5	1.3 x 10^5	4.1 x 10^5
10	2.6 x 10^4	1.4 x 10^5	4.2 x 10^4

(Source: Envir-Health, 2002)

Microbiological Characteristics of Sediment Samples

Results indicate that heterotrophic bacteria were predominants in all the samples with values ranging from 6.2 x 10^5cfu/g to 2.1 x 10^5cfu/g hydrocarbon utilizing bacteria which constitute a major fraction of the total heterotroph. This is indicative of a high input of hydrocarbon into the environment. Total coliforms, which are indicators of feacal contamination, were minimal in almost all the samples. Total fungal counts ranged from 1.2 x 10^5cfu/g to 4.3 x 10^5cfu/g. The ratio of hydrocarbonoclastic microorganisms to total heterotrophic microorganisms at all sampling stations were in excess of 1.0% indicating previous significant crude oil input into the environment. The hydrocarbon-utilizing microorganisms isolated included *Bacillus sp, Achromobacter sp, Pseudomonas sp, Desulfovibrio sp, Trichoderma sp, Acremonium sp,* etc.

6.0 Conclusion

The Department of Petroleum Resources, DPR (1991) in the Environmental Guidelines and Standards for Petroleum Industries in Nigeria, stipulates in Part VIII B Section 4 and 8 the guidelines for management of mystery oil spills and liability and compensation arising therefrom. The provisions are stated below:

Mystery Spills (Spills of Unknown Origin)

"An operator shall be responsible for the containment and recovery of any spill discovered within his operational area, whether or not their source is known. The operator shall take prompt and adequate steps to contain, remove and dispose of the spill. Where it is proven beyond doubts that an operator has incurred costs in cleaning up a spill for which he is not responsible, the operator, shall be reasonably compensated, up to the extent of recovering all expenses incurred, including reimbursement of any payments for any damage caused by the spill, through funds established by the Government or the oil industry for that purpose".

Liability and Compensation

Liability

"A spiller shall be liable for the damage from a spill for which he is responsible. Where more than one spiller is responsible and liable, their li. ·ility should be joint and several".

Compensation

"In a case where compensation is sought for damages from a spill incident, the Compensation Tribunal shall determine the damages suffered as a result of the spillage or operations, and liability and take appropriate steps to ensure that adequate compensation is paid' "It shall be the responsibility of the Compensation Tribunal to determine the quantum of compensation payable".

Etiama oil spill was from a known source, the 24" Ogoda – Brass pipeline belonging to Nigerian Agip Oil Company (NAOC). Meanwhile, the provision that spills caused by sabotage do not attract any compensation may have been applied here. However, to

ensure environmental conservation and in line with NAOC's HSE Policy, the company cleaned up the spill, carried out Post impact assessment and embarked on the re-vegetation of the destroyed mangrove vegetation of the impacted site, amongst other things.

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