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Post impact assessment of a petroleum effluent dump site located in Midwestern Nigeria

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ABSTRACT

The study is a post impact assessment of a petroleum effluent dump site located in Midwestern Nigeria carried out with a view to investigating the implication of exploration activities earlier carried out in the area and the vulnerability of the area to future developmental program. The effluent dump was nearly circular measuring about 50m - 60m in diameter. The study area was selected as the area radially situated on the periphery. The area was divided into three areas: areas covering the periphery of the effluent dump to 50m radius (i.e. cir. 0 – 50m); areas radially covering 50 – 100m (i.e. cir. 50 – 100m), and the area covering 100 – 200m radius (i.e. cir. 100 – 200m). The control was taken as an area located 500m from the effluent dump site. The mean ambient air quality measurements for the different radial dimensions from the effluent dump site were within Federal Ministry of Environment/Department of Petroleum Recourses (FMEnv/DPR) limits. No significant changes in soil pH were observed. Heavy metal composition of soil was significantly higher near the periphery of the dumpsite than away near to the control site. The mean plant density of the project site showed that herbaceous layer was 13 plants per meter squared very close to the effluent dump site compared to 51 plants in the control site. There were no trees near the effluent dump site, but there were 303 trees/ha in the control site. Vegetation of the farmlands situated between 100m -200m comprised mainly Cynodon dactylon, Cyperus iria, Eleusine indica, Euphobia heterophylla, Manihot esculenta, Paspalum conjugata, Sida acuta, Zea mays. Musa paradisiaca. Soils very close to the effluent dumpsite were rich in hydrocarbon degrading microorganisms than soils in the control site.

Keywords: Dump site, exploration, flow station, impact assessment, niger delta, petroleum effluent, pollution, waste.

INTRODUCTION

The environment is increasingly exposed to changes resulting from both natural and anthropogenic sources. These changes could be drastic and as such affect the ecosystem substantially. Oil pollution is prevalent in Nigeria, being a major oil-producing country. Crude oil and its refined products account for over 90 % of Nigeria's national income. The petroleum industry has eventually created economic boom for Nigeria and at the same time led to environmental and socio-economic problems[1]. With an ever increasing global population, there is a concomitant increase in the demand for petroleum and petroleum products, which apparently constitutes a source of Environmental Pollution. The environmental impacts associated with exploration and exploitation of crude oil has been a major area of experimental research in Nigeria in the last three decades or so. Oil spills destroy farmlands, with detrimental impact on agricultural crops. This usually causes instantaneous negative and often violent reactions

with demand for compensations by the communities in the oil-producing areas such as occur in the Nigerian Niger Delta.

Eventually, oil exploration in the Niger Delta has long been marked by protests by local communities about the negative impact of the oil industry, corruption and the failure of oil wealth to be translated into better living conditions. More recently, armed groups and criminal gangs have explicitly sought resource control on behalf of the oil producing areas, and have engaged in theft of oil and in acts of violence which are sometimes claimed as retribution for the treatment of the people of the Niger Delta by the oil industry.

Frequent oil spills are a serious problem in the Niger Delta. The failure of the oil companies and regulators to deal with them swiftly and the lack of effective clean-up greatly exacerbates the human rights and environmental impacts of such spills. The activities involved in petroleum exploration and production produce wastes of varying chemical compositions, which are generated at each phase of the operation. Some of these wastes are emptied into burrow pits, as was the case of the present study area. Others are emptied as waste water into rivers and the sea[2]. The disposal of these wastes in the Niger Delta has polluted land and water, damaging fisheries and agriculture, undermining the human right to an adequate standard of living. However, there have been reports by some oil exploration companies of the cleanliness of operations within their industrial estates.

The essence of the study therefore is to obtain information on the implication of exploration activities earlier carried out in the area and the vulnerability of the area to future developmental program. This will, in case of a negative impact suggest remedial environmental conservation program. The scope of the study covers field study and laboratory analyses of field data which include air quality, soil physicochemistry, vegetation and microbial studies, as well as a number of fauna encountered in the study area.

Figure 1: Photograph of the effluent dump.

MATERIALS AND METHODS

Study sites description

The study area is a burrow pit *cum* petroleum effluent dump belonging to a Flow Station (name withheld) located in Edo State of Nigeria. The area is a location of 200m radius from the effluent pond; surrounded by farm lands and cash crop plantation, with absence of water bodies. The area is an intensively farmed secondary forest and consists of thickets and fallow land highly denuded by human activities at various stages of regeneration. Petroleum sludge, expended drill muds as well as other bye products and petroleum wastes emanating from activities at the Flow Station are directed into the burrow pit. An uncontaminated site, about 500m from the effluent dum was used as the control. The control site had no record of crude oil spillage or exploration activities prior to sampling. Crops cultivated within the study area, near the study area and in the control sites include maize (*Zea mays*), cassava *(Manihot esculenta*), oil palm (*Elaeis guineensis*), plantain (*Musa spp*.), and banana (*Musa paradisiaca*).

Field Reconnaissance

Field reconnaissance studies were carried to estimate the extent of pollution on surrounding soil, using the presence and absence of some flora and fauna, and developmental defects on some flora. A reconnaissance survey was also important in order to obtain a visual assessment of the vegetation/ land use type.

Sampling Design and Techniques

The effluent dump was nearly circular measuring about 50m - 60m in diameter. The study area was selected as the area radially situated on the periphery. The area was divided into three areas: areas covering the periphery of the Effluent dump to 50m radius (i.e. cir. 0 – 50m); areas radially covering 50 – 100m (i.e. cir. 50 – 100m), and the area covering 100 – 200m radius (i.e. cir. 100 – 200m) (Figure 1). The control was taken as an area located 500m from the effluent dump site.

In each of the radial designations, sampling was randomly done as an average of measurements taken from 5 randomly placed quadrats measuring 5m x 5m within each circular demarcation.

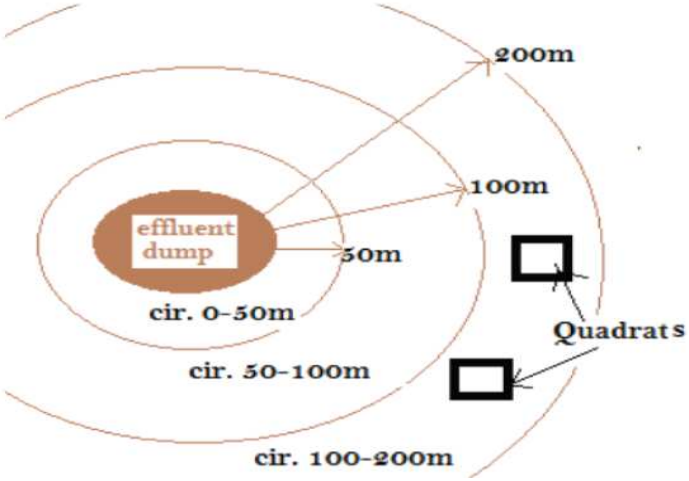

Figure 2: A representation of circular demarcation of the study area about the effluent dump; also showing random placement of 5 quadrats within each radial demarcation.

Samples were also collected from the control site. All samples were air dried, sieved with 2mm sieve, labeled and forwarded to the laboratory for analysis.

Vegetation Studies

The vegetation studies were carried out at the same sampling stations with soil studies. Random quadrat sampling technique was employed in the field. Quadrat was randomly placed within each radial demarcation in 5 random replications so that average observation was recorded per demarcation. Although sampling sites were selected randomly, a bias was introduced to ensure the inclusion of the representative vegetation/land use and microclimatic types. Preliminary observations established that the fields were not covered by primary forest vegetation. On the basis of this, quadrat dimension of 5m x 5m for herbaceous weeds and 10m x 10m for tree and shrub species. The different plant species at the sampling points were separately kept in labeled polythene bags and then taken to the laboratory where they were pressed and identified.

Qualitative visual observation was carried out at the entire area. Quantitative determination of plant species density was confined to quadrat established within each ecotype. A general survey of the area was also carried out identifying all farm lands, recording crop type, stage of development and state of health.

Air Quality

Digital air quality equipment was used to determine the concentrations of NH_3, SO_2, CO, CO_2 and NOx, VOC and TSP in the air. At each sampling region, readings were taken continuously for 15 minutes and extrapolated to an hourly reading for three hours per sampling region, taken as three replicate readings.

Soil Physicochemical Analyses

In the laboratory, soils were dried at ambient temperature (22-25^{o}C), crushed in a porcelain mortar and sieved through a 2mm (10 meshes) stainless sieve. Air-dried <2 mm samples were stored in polythene bags for subsequent analysis. The <2 mm fraction was used for the determination of selected soil physicochemical properties and the

heavy metal fractions. Determination of organic carbon followed the methods of Osuji and Nwoye[3]. Soil total nitrogen was determined by the Kjeldahl Digestion Method. Determination of soil available phosphorus was according to Bray and Kurtz[4]. Exchangeable cations (Na, K, Ca and Mg) were determined following the methods of Tekalign *et al* [5], whereas determination of exchangeable acidity was according to Marscher[6]. Heavy metal fractions (Fe, Mn, Zn, Cu, Cr, Cd, Pb, Ni, V) were determined by AAS [7].

Identification of Soil Microorganisms

Isolation and characterization of bacterial and fungal oil degraders was carried out using standard methods [8, 9].

RESULTS

Results of the mean ambient air quality measurements for the different radial dimensions from the effluent dump site are presented in Table 1. The results indicate that all parameters were within statutory limits. The project area thus has very low levels of air pollution indicators as all measured parameters were within Federal Ministry of Environment/Department of Petroleum Recourses (FMEnv/DPR) limits. The Nigerian Ambient Air Quality Standards are given in Table 1 in parentheses for comparison.

Table 1: Air quality parameters measures within the study area

Location	Air quality parameters (µg/m^3)			
	Particulate (250ug/m^3)	NO_2 (75-113 µg/m^3)	SO_2 (26 µg/m^3)	CO (11.4-22.8 µg/m^3)
cir. 0-50m	65.3	11.2	17.2	7.1
cir. 50-100m	63.9	10.3	16.3	5.8
cir. 100-200m	58.3	9.4	12.2	3.4
Ctrl	16.6	2.4	8.2	1.9

Limits/Benchmark values are provided in parentheses[10]

No significant changes in pH were observed (Table 2). Values of pH ranged from 5.71 near the dump site (cir. 0 – 50m) to 6.12 between 50 -100m. Organic carbon content of soil was higher in the control soil (1.49%) compared to areas within 100m radius of the petroleum effluent dump site. In contrast, Ekundayo and Obuekwe[11] reported increases in organic carbon of oil-polluted soils in Southern Nigeria. Potassium content of soil was higher near the effluent dump site (0.26 meq/100g soil) compared to 0.19 meq/100g soil in the control. However, calcium content of soil was highest in the control soil (5.89 meq/100g soil) compared to very near the effluent dump site (2.16 meq/100g soil). The present findings contradict the previous reports [12, 13] that there is increase in exchangeable Ca^{2+} contents as a result of crude oil. This, according to them, can be also attributed to rapid decay and mineralization of organic and mineral materials in the soils. Reduction in K^+ and Na^+ might be due to nutrient immobilization consequent upon the formation of complexes in the soil after degradation and uptake. The observed increase in the phophorus content of the crude oil-contaminated soil might be due to the increase in soil pH resulting from inadvertent amendment of polluted soil by the presence of the dead plants. This finding supports earlier reports that increasing pH increases weathering and mineralization rates [14]. This could have increased phosphorus availability and reduced its fixation [15] to a pH of about 5.5-6.0, and thereafter, phosphorus availability started to decrease in areas of low oil concentrations. Siddiqui and Adams[16] had also recorded increased P with increasing concentrations of diesel hydrocarbons up to a stage and then it declined. Soils contaminated with petroleum products have been shown to have large increases in nitrogen and phosphate contents[17].

Table 2: Some physiochemical parameters of soil collected within radial demarcations from the petroleum effluent dumpsite

	pH	EC (µS/cm)	Org.C <……(%)……>	T.N	EA	K <……(meq/100g soil)……>	Ca	Mg	Av. P <..…(mg/kg)……>	NH_4N
cir. 0-50m	5.78	530	0.82	0.064	0.34	0.26	2.16	0.45	9.11	15.79
	(0.08)	(14)	(0.06)	(0.003)	(0.02)	(0.04)	(0.09)	(0.03)	(0.74)	(2.03)
cir. 50-100m	6.02	560	0.77	0.069	0.48	0.24	4.46	0.77	9.03	13.64
	(0.29)	(23)	(0.09)	(0.006)	(0.02)	(0.02)	(0.16)	(0.04)	(0.33)	(1.11)
cir. 100-200m	5.68	498	0.98	0.089	0.46	0.17	6.09	0.69	6.43	8.53
	(0.09)	(34)	(0.11)	(0.004)	(0.04)	(0.02)	(0.32)	(0.03)	(0.47)	(1.21)
Ctrl	5.83	260	1.49	0.112	0.42	0.19	5.89	0.67	3.14	4.92
	(0.15)	(32)	(0.06)	(0.008)	(0.03)	(0.01)	(0.52)	(0.03)	(0.13)	(0.15)

EC electric conductivity, Org. C organic carbon, TN total nitrogen, EA exchangeable acidity.

Table 3 shows heavy metal composition of soil within the radial demarcations from the petroleum effluent dumpsite. Iron in the soil was higher near the dump site (1288.3 mg/kg) than far way in the control soil (950.3 mg/kg). Copper in the soil was higher in the soil (5.7 mg/kg) near the dump site than away in the control soil (2.2 mg/kg). Total hydrocarbon content (THC) ranged from 45.48 – 10.63 mg/kg, with higher values near the dump site.

Table 3: Heavy metal composition of soil (mg/kg) within radial demarcations from the petroleum effluent dumpsite.

	Fe	Mn	Zn	Cu	Cr	Cd	Pb	Ni	V	THC
	<……mg/kg……>									
cir. 0-50m	1288.3	11.8	12.6	5.7	3.1	6.4	1.91	3.6	2.8	45.48
	(18.1)	(0.9)	(1.7)	(0.1)	(0.2)	(0.4)	(0.42)	(0.2)	(0.2)	(6.22)
cir. 50-100m	1195.6	14.5	6.5	5.5	2.7	3.4	0.85	1.9	1.6	25.65
	(23.5)	(1.5)	(0.8)	(0.2)	(0.1)	(0.1)	(0.18)	(0.5)	(0.3)	(2.14)
cir. 100-200m	1085.7	13.2	6.8	2.8	2.3	2.4	0.56	1.8	1.8	19.36
	(12.2)	(2.3)	(0.5)	(0.1)	(0.1)	(0.2)	(0.11)	(0.4)	(0.3)	(3.55)
Ctrl	950.3	28.7	8.8	2.2	2.3	2.5	0.50	1.3	1.8	10.63
	(22.4)	(3.5)	(1.1)	(0.1)	(0.2)	(0.2)	(0.09)	(0.4)	(0.4)	(2.24)

The vegetation is a degraded forest area mixed with trees and shrubs, as well as farm fallows. Crop farmlands also abound in the area, especially after 100m away from the effluent dumpsite. The mean plant density of the project site showed that herbaceous layer was 13 plants per meter squared very close to the effluent dump site (cir. 0 – 50m). However, within 50 -100m radius of the plant density were 29 herbs per squared meter as against 51 plants in the control site (Table 4). Shrub layer was 310 shrubs/ha very close to the effluent dump site (cir. 0 – 50m) compared to 1284 shrubs in the control. There were no trees near the effluent dump site, 105 trees/ha between 100m and 200m of the dumpsite, compared 303 trees/ha in the control site.

Table 4: Characteristics of vegetation within each radial demarcation in the study areas

Vegetation	Mean plant density		
	Herbaceous layer (No./m^2)	Shrub layer (No./ha)	Total No. of Trees (No./ha)
cir. 0-50m	13	310	0
cir. 50-100m	29	523	19
cir. 100-200m	38	1102	105
Ctrl	51	1284	303

C_0, control= 500m away

Lumbering activity was not observed within the area. The herb layer of the fallow lands very near the dumpsite (cir. 0-50m) were dominated by *Cyperus iria, Desmodium salicifolium, Mimosa invisia,* and *Panicum maximum.* Other weed species included *Phyllanthus amarus, Schrankia leptocarpa, Solenostemon monostachyus,* and *Urena lobata* (Table 5). Between cir. 50 – 100m, weeds were dominated by *Cyperus haspan , Digitaria horizontalis , Aneilema aequinoctiala,* and *Chromolaena odorata.* Others weeds were *Anthonotha macrophylla, Euphobia heterophylla, Ipomoea involucrata, Isoberlina doka, Panicum maximum, Paspalum scrobiculatum, Phyllanthus amarus,* and *Physalis micrantha.* Lianas were also common in some of the trees present beyond 100m from the petroleum effluent dump site. The epiphytes were mainly ferns on palm trees. Anoliefo *et al.*[18] identnified a number a plants in an oil-polluted auto-mechanic workshop, suggesting therefore that these weeds could have a tolerance for oil. These weeds included *Tridax procubens, Acanthospermum hispidum, Euphorbia heterophyllia, Eragrostis tenelia, Panicum maximum,* and *Fluerya aestuans.* The capability for *Talinum triangulare, Celosia trigyna, Corchorus olitorus, Vernonia amygdalina,* and *Telferia occidentalis* as well as grasses like *Eleucine indica, Cynodon dactylon, Panicum maximum, Euphorbia hirta, Chromolaena odorata* for recovery of heavy metals from soil has also been reported[19, 20].

The land use pattern encountered in the field could be grouped as both industrial and agricultural. The industrial land use includes flow stations, wellheads and their access routes. The agricultural include farmlands and bush fallows constitute the bulk of the land use around the project sites. The farms were normally fragmented and in pockets. The most common cropping system is the patch intercropping involving the growing of two or more crops in a given piece of land in small groups. The common crop combination was maize – cassava. Farmlands were encountered beyond 100m from the dump site, and had crops such as cassava (*Manihot esculenta*), okra (*Hibiscus esculentus*), pawpaw (*Cariaca papaya*), maize (*Zea mays*), plantain (*Musa paradisiaca*), and banana (*Musa sapientum*), and a variety of leafy vegetables (Table 6). Most of the crops are grown as crop mixtures or intercrop.

Table 5: Composition of weeds within and around the petroleum effluent dumpsite

Weed Species	C_{trl}	cir. 0-50m	cir. 50-100m	cir. 100-200m
Ageratium conyzoides	+++	-	-	-
Andropogon gayanus	++	-	-	++
Aneilema aequinoctiale	++	-	++	-
Anthonotha macrophylla	-	-	+	-
Bryophyllum pinnatum	++	-	-	-
Chloris pilosa	+	-	-	+
Chromolaena odorata	++	-	++	++
Commelina diffusa	++	-	-	-
Cynodon dactylon	-	-	-	++
Cyperus haspan	+++	-	+++	++
Cyperus iria	-	++	-	+
Daniellia oliveri	+++	-	-	+
Desmodium salicifolium	++	++	-	-
Desmodium scorpiurus	++	-	-	++
Digitaria horizontalis	++	-	++	-
Diodia sarmantosa	++	-	-	-
Echinochloa obtusiflora	+	-	-	+
Eleusine indica	++	-	-	++
Euphobia heterophylla	++	-	+	++
Ficus exasperate	++	-	-	-
Ipomoea involucrata	-	-	++	-
Isoberlina doka	-	-	+	+
Mimosa invisia	-	++	-	-
Momordica charantia	++	-	-	-
Panicum maximum	++	+++	++	+
Paspalum conjugate	+	-	-	++
Paspalum scrobiculatum	++	-	+	-
Pennisetum pedicellatum	++	-	-	++
Phyllanthus amarus	++++	+	++	++
Physalis micrantha	++	-	+	-
Portulaca oleracea.	-	-	-	++
Schrankia leptocarpa	-	+	-	-
Scoparia dulcis	-	-	-	++
Sida acuta	++	-	-	++
Sida garckeana	++	-	-	-
Sida rhombifolia	++	-	-	-
Solenostemon monostachyus	-	+	-	-
Spigelia anthalmia	++	-	-	-
Synedrella nodiflora	++	-	-	-
Urena lobata	+	+	-	-

+ Present but scanty, ++ present, +++ present and abundant, +++++ very predominant, - absent. C_1= periphery of the Effluent dump/burrow pit (0-5m); C_2=5- 25m; C_3=25-50m; C_4=50-100m; C_5=100-200m; C_0, control= 500m away

Vegetation of the farmlands situated between 100m -200m comprised mainly *Cynodon dactylon, Cyperus iria, Eleusine indica, Euphobia heterophylla, Manihot esculenta, Paspalum conjugata, Sida acuta, Zea mays. Musa paradisiaca.* Most other weeds were cleared off by the farmers. Most of the plants encountered near the petroleum effluent dump site were predominantly chlorotic and necrotic. Only a few crops beyond 100m of the dump site were chlorotic and necrotic: they were mostly normal.

Atlas and Bartha[21] reported that the addition of crude oil to an ecosystem will enrich primarily the micro-organisms capable of utilizing the hydrocarbons and secondary micro-organisms capable of utilizing metabolites produced by the oil-utilizing microorganisms. The soil microbes include bacteria and fungi. These contribute substantially to the re-cycling of nutrients and materials within the ecosystem. The present study emphasizes the role of bacteria and fungi in biodegradation of hydrocarbon which is the main source of soil pollution in the study area (Table 7). The bacteria population included *Bacillus* sp., *Klebsiella* sp., *Pseudomonas* sp., *Staphylococcus* sp., *Achromobacter* sp., *Aeromonas* sp., *Clostridium* sp., *Escherichia coli*., *Flavobacterium* sp., *Micrococcus* sp, and *Serretia* sp (Table 7). The heterotrophic bacterial counts was 3.9 x 10^5 cfu/g soil in cir. 0-50m compared to 7.4 x 10^5 cfu/g soil in the control area. Percentage hydrocarbon degrading bacteria varied from 14.10% to 53.84%. Hydrocarbon degrading bacteria count decreased away from the effluent dump site. Consequently, the soils have an in-built mechanism of self-purification in the event of low levels of crude oil contamination. The predominant isolates of the fungal population were *Mucor* sp., *Penicillium* sp., *Aspergillus* sp., *Trichoderma* sp., *Cladosporium* sp .and *Rhizopus* sp. Heterotrophic fungi ranged from 3.6 x 10^5 in the control to – 4.7x 10^5 in cir.0-50m. There was reduction in fungi

counts away from the effluent dump site. Comparatively, hydrocarbon degrading fungi were more than their bacterial counterparts in each treatment level considered (Table 7). The effect of oil spills on soil also leads to an enrichment of the oil–degrading microbial population. However, a decrease in microbial population exposed to crude oil and its products have also been documented[22, 23]. Atlas[24] reported that certain crude oils contain toxic components that are bacteriostatic. These inhibitory effects have also been reported to depend on concentrations[25].
A number of microorganisms like *Pseudomonas* were identified as hydrocarbon degrading microorganisms. No single micro organism has been found to be able to completely degrade a petroleum hydrocarbon molecule. However, different species or strains of the same species may be capable of degrading different groups of hydrocarbons, found in oil[26]. Different naturally occurring species of *Pseudomonas* are known to contain plasmids with the relevant genes for the degradation of different hydrocarbons [27]. A number of bacterial and fungal genera responsible for oil degradation in both soils and aquatic environment have been identified[11, 28, 29, 30]: *Pseudomonas, Achrobacter, Bacillus*, *Micrococcus, Nocardia, Trichoderma, Penicillium, Aspergillus* and *Morteilla.*

Table 6: Plants species composition of vegetation / agricultural land use types within the project area.

Study Area	Vegetation /Agricultural Land use Type	Commonest Plant Species	Weeds		Crops			
			Chlorotic	Necrotic	Normal	Chlorotic	Necrotic	Stunted
cir. 0-50m	Farmlands	NC	NC	NC	NC	NC	NC	NC
	Fallow lands	Same as listed on Table 1	***	***	NC	NC	NC	NC
cir. 50-100m	Farmlands	NC	NC	NC	NC	NC	NC	NC
	Fallow lands	Same as listed on Table 1	**	*	NC	NC	NC	NC
cir. 100-200m	Farmlands	*Cynodon dactylon, Cyperus iria, Eleusine indica, Euphobia heterophylla, Manihot esculenta, Paspalum conjugata, Sida acuta, Zea mays. Musa paradisiaca*	_	_	***	*	*	*
	Fallow lands	Same as listed on Table 5						
Ctrl	Farmlands	*Ageratium conyzoides, Aneilema aequinoctiale, Cariaca papaya, Cyperus haspan, Daniellia oliveri, Desmodium salicifolium, Desmodium scorpiurus, Digitaria horizontalis, Echinochloa obtusiflora, Eleusine indica, Euphobia heterophylla, Hibiscus esculenta, Manihot esculenta, Musa paradisiaca, Paspalum scrobiculatum, Pennisetum pedicellatum, Phyllanthus amarus, Physalis micrantha, Terfairia occidentalis, Zea mays,*	*	_	***	_	_	_
	Fallow lands	Same as listed on Table 5	*	_	NC	NC	NC	NC

*NC no cultivation, *scanty **moderately present, ***heavy presence, - absence.*

Table 7: Microbial composition of soil within radial demarcations from the petroleum effluent dumpsite. Petroleum hydrocarbon degraders are asterisked

Treatments	Bacterial Isolate Identified	Bacterial counts x10^5	Hydrocarbon degrading bacteria x10^5	Percentage hydrocarbon bacteria degraders	Fungi Isolated	Fungal counts x10^5 cfu/g	Hydrocarbon degrading fungi x10^5	Percentage hydrocarbon degrading fungi
cir. 0-50m	**Bacillus* sp., *Klebsiella* sp., *Pseudomonas* sp., *Staphylococcus* sp., *Achromobacter* sp., *Clostridium* sp., *Micrococcus* sp., *Serretia* sp.	3.9	2.1	53.84	**Mucor* sp., **Penicillium* sp., **Aspergillus* sp., *Trichoderma* sp., *Cladosporium* sp., *Rhizopus* sp.	4.7	2.8	59.57
cir. 50-100m	**Bacillus* sp., **Klebsiella* sp., **Pseudomonas* sp., **Staphylococcus* sp., *Achromobacter* sp., *Clostridium* sp., *Flavobacterium* sp., *Micrococcus* sp., *Serretia* sp.	5.4	1.7	31.48	*Aspergillus niger.*, *Penicillium* sp., **Mucor* sp., *Candida* sp., *Cladosporium* sp., **Penicillium* sp., *Rhizopus* sp.	4.2	1.8	42.85
cir. 100-200m	**Bacillus* sp., **Klebsiella* sp., **Pseudomonas* sp., **Staphylococcus* sp.., *Achromobacter* sp., *Aeromonas* sp., *Clostridium* sp., *Escherichia coli*., *Flavobacterium* sp., *Micrococcus* sp.	7.8	1.1	14.10	*Aspergillus niger.*, *Penicillium* sp., **Mucor* sp., *Candida* sp., *Cladosporium* sp., **Penicillium* sp., **Aspergillus* sp., *Trichoderma* sp., *Rhizopus* sp.	3.9	0.4	10.26
Ctrl	* *Pseudomonas* sp., **Bacillus* sp., **Klebsiella* sp., *Aeromonas* sp., *Clostridium* sp., *Escherichia coli*, *Flavobacterium* sp.	7.4	1.8	24.32	*Aspergillus niger.*, *Penicillium* sp., **Mucor* sp., *Candida* sp., *Cladosporium* sp., **Penicillium* sp., **Aspergillus* sp., *Trichoderma* sp., *Rhizopus* sp.	3.6	0.7	19.44

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