Jr. of Industrial Pollution Control 20 (1) (2004) pp. 73 -92

AN INTEGRATED APPROACH TO ENVIRONMENT SITE ASSESSMENT OF PAST IMPACTED (PI) WASTE PIT AND BORROW PIT IN THE TROPICS (CASE STUDY)

AYADE, B.B.

Department of Microbiology, Delta State University
Abraka, Nigeria

Key words : Integrated approach, site sssessment, past impacted area, waste and borrow pits, tropics.

ABSTRACT

In the process of oil field development which involves bush clearing, ditching and drilling, a lot of waste such as drilling muds, chemical wastes, radioactive wastes and other associated wastes including domestic wastes are generated. Wastes generated during drilling of oils are confined in excavated pits known as waste pits located very close to each well head and within its acquired location. Borrow pits are also created through the excavation soils for use in construction of roads, solidification of well head basements and construction of other operational facilities. In the long or short term some of the pits usually end up as repositories for different kinds of wastes from the production facilities. These waste pits and borrow pits are classified as Past Impacted Area (PIA). Detailed study of past impacted area were initiated as an innovative site assessment tool that can be effectively used to determine the ecological and socio-economic impacts of the sites, acquire site specific qualitative and quantitative data on the characteristics and spread of contaminants, identify sources, pathways and receptors of contaminants and recommend cost effective strategies for contaminated site rehabilitation. For a good indicators were established. High levels of heavy metals and other physico-chemical parameters were recorded in the borrow and waste pits, except dissolved oxygen which was low. Total Petroleum Hydrocarbon were also high in the

soil, sediments of borrow pits and waste pit. Phytoplankton and zooplankton were distributed in both borrow and waste pits. There was however no significant difference (P>0.05) between the observed variation in abundance amongst the major divisions involved. Risk Based Corrective Action (RBCA) site classification procedure was employed. The initial response action for highly contaminated area involves restricting access to the sites by fencing. This is to protect human health impact through either inhalation of volatile organic compounds or ingestion of contaminated surficial sediments. After instituting the access restrictions, the general remedial/ corrective actions proposed for the impacted surface waters and soils/sediments can then be implemented.

INTRODUCTION

Description of study area

The study area lies within the warm and humid tropical climatic belt of the Western Niger Delta Region of Nigeria. The region is characterized by high annual rainfall (2500 mm), high relative humidity (85%), and daily temperature range of 26^0C to 36^0C. The natural vegetation has largely disappeared and replaced by wild and plantation forests of palm and rubber. The entire zone is rich in species but highly fragile and sensitive to development. The geology of the study area is that of the coastal sedimentary lowlands which lies immediately north of the coastal swam of the Niger Delta.

Description of existing social environment

The communities are basically rural and the tempo of economic activities is generally low. Apart from the activities. The economy of the communities is therefore based on the exploitation of the immediate environment especially agriculture. The activities of oil companies has however generated trading business and paid employment opportunities.

Description of the borrow pit

The borrow pit covers an area of 85/24m with an average depth of 1.8m. the surface water is defined by a reddish brown coloration, an indication of the die back of organic matter. Vegetation cover around the pit is thick and luxuriant showing high nutrient status of surrounding soils.

Description of the waste pit

The waste pit is defined by a cover of fresh (grass) vegetation, the edges of the pit have been eroded over the years due to surface erosion. The waste pit is defined by an average area of 2-/16m. Part of the pit has been backfilled by surface erosion and natural weathering process. The base of the pit is covered by luxuriant grasses. Vegetation cover within the pit is stressed due to nutrient depletion.

MATERIAL AND METHODS

A plan was set up for data collection, using boring and coring as well as monitoring wells for the site assessment. The data collection plan included samples to be taken at three pristine sites to establish background values of relevant contaminants.

Fieldwork included an intensive programme of site investigation with sampling of soil and sediments, installation of monitoring wells and sampling of ground and surface waters. The sampling sites and stations covered both the terrestrial and aquatic environment for soil, surface and underground water chemistry, ecology and socio economics. The sampling strategy was designed to collect site specific representative data, he truly reflects the existing conditions of the waste-pit and borrow pit utilizing the cross sectional sampling design. Sampling points were also randomly selected with respect to identified pollutant sources. Ground water samples were collected from ten monitoring boreholes drilled for the purpose. The monitoring boreholes were located based on the foreknowledge from Vertical Electrical Sounding (VES) of the ground water flow direction in the area.

Socio-economic and cultural studies were focused on the population within the zone of project impact. Questionnaires were administered in the various communities within the study areas.

In all cases ASTM/APHA recommended guidelines were used for sampling and analysis and international standard operating procedures including quality control measures were applied throughout the programme.

Water quality

Composite water samples were taken at five imaginary ends of the cross from the surface and near the bottom using a 2-litre Hydrobios Water Sampler. Physico-chemical parameters were the measured using recommended methods.

Soils and sediments

Soil samples were taken at four levels: 0-15cm, 1m, 2m, 3m and 4m depths using stainless steel hand auger in the pits. Composite samples were also taken at four imaginary ends of the cross and at 1m, 2m, 3m and 4m away from the edge of the pit for contaminant plume delineation. Samples for microbiological analysis were wrapped in aluminum foil and refrigerated before analysis.

Sediment samples were collected from the water stations by means of an Eckman Sediment Grab. After sieving to remove dirt and debris, and draining the water, the sediment samples were placed in sampling containers, labeled & stored in ice-chest box to prevent microbial degradation of the hydrocarbon.

Geology/Hydrology studies

A total of three boreholes were drilled in the study area, by undisturbed percussion drilling method. Justification for location of the boreholes was based on the need to investigate the underground water quality of the study sites.

The drilled boreholes were samples for formation description at regular interval of 10ft (3m). Water sample was collected from each of the boreholes. The depth to static water level was measured after the completion of each borehole. The borehole formation samples were lithologically logged and correlated for stratigraphical evaluation and delineation of the structural disposition of the subsurface layers.

Physical and chemical analyses

Physical and chemical analyses proceeded in accordance with the methods of American Public Health Association (APHA) and ASTM.

ECOLOGICAL PROGRAMME

Phytoplankton composition and diversity

In each water sampling point, phytoplankton was collected just below the water surface with a quantitative 55-micron mesh tow net attached to a cowl with an aperture diameter of 17 cm. Fixed into the inside of the cowl was a flow meter, which measured the flow rate of the water, which passed through the net. The catches were immediately removed from the net, bottled and preserved in a solution of 4% formaldehyde. The phytoplankton were examined in the laboratory using a Leitx Orthoplan Universal Wide- field Research Microscope equipped with tracing and measuring devices. One ml of the concentrated samples was introduced into a counting chamber and an average of 10 rows counted. The average frequency distribution of the different species was recorded. Diversity index D and Dominance C^0 were calculates from the following expressions;

$$D = \frac{N_0}{\sqrt{N_x}} \qquad C^0 = \sum_{i=1}^{N_O} \left(\frac{ni}{N}\right)^2$$

Where, Nx = No. of individuals in cells/station
Ni = Importance value for each species
N = Total of importance values
No = Number of species in sample.

Zooplankton composition and diversity

For qualitative studies, zooplankton hauls were made with a 55-micron mesh tow net fitted with a flow meter. Zooplankton collected were preserved in buffered 4% formain in 200 ml plastic containers. For quantitative studies forty (40) liters of water were filtered through a 55 micron mesh plankton net and reduced to 50 mL concentration. In the laboratory , counting was done in a 1 mL Koltwitz counting chamber with grids. Row after row of the counting chamber was examined by means of an Olympus Vanox Research Microscope and the numbers of individual species recorded. Zooplankton numbers were computed from the equation :

$$\frac{N x S x 1000}{V}$$

Where,

N = number of zooplankton in 1 mL of samples
S = Volume of sample (50 mL)
V = initial volume of sample (40 l)

Fauna

The fauna was investigated by the methods outlined below. Two types of sampling were carried out at each point for the estimation of abundance and diversity of fauna. Collection of intertidal macrofauna was done with a one square meter quadrant. Organisms were identified and counted in situ, and specimen that could not be identified in the field were collected and preserved in some quantities of 40% formaldehyde.

Sorting of organisms from the residue and counting were done under the binocular dissecting microscope and the compound microscope. Identification was carried out from whole specimens and prepared slides using relevant identification manuals and keys. All indices of diversity used in statistical analyses were adapted from Odum (1971) and Zar (1983).

All field samples were examined using the binocular dissecting microscope. Taxonomic identifications of all specimens were confirmed using relevant manuals and literature.

VEGETATION STUDIES

Field procedure

The rapid assessment method was used to provide information on plant species composition and structure. For the determination of frequency and density of the species, a linear diagnostic sampling technique using multiple 1m x 1m quadrants, was employed to provide maximum chance of encountering most of the species. All plants within each quadrant were identified and listed while the unidentified ones were collected, pressed and taken to the herbarium for correct identification.

Field procedure

The rapid assessment method was used to provide information on plant species composition and structure. For the determination of frequency and density of the species, a linear, diagnostic sampling technique using multiple am x am quadrants, was employed to provide maximum chance of encountering most of the species. All plants within each quadrant were identified and listed while the unidentified ones were collected, presses and taken t o the herbarium for correct identification.

Structure

In order to quantify the above ground biomass of the herb layer, eight 1m x 1m quadrants were selected. All the plant materials within each quadrant were cut, sub –samples and taken to the laboratory for analysis of dry matter according to Chapman (1976). An analysis of the life-form structure of the plant species encountered within the study area was carried out according to the Raunkiaer life-form classification (Harrison, 1976).

Crop and plant pathology

The state of health of crops and vegetation were noted while infected crops and vegetation were collected and keep in moistened polythene bags and transported to the laboratory for further studies. Laboratory studies included isolation and characterization of pathogenic fungi and bacteria from infected plant materials.

Herbarium and laboratory procedure

Unidentified pressed specimens were taken to the laboratory and identified using the Flora of West Tropical Africa (Hutchinson and Dalziel, 1958-1968) and reference to herbarium specimens. The plant biomass was obtained by drying the plant material in the oven at 105^0C till they attained a constant weight. The dry matter to fresh weight ratio of each sample was used to convert field fresh weight to dry weight.

Plant tissue analysis

Plant tissues were analysed to assess bioaccumulation of contaminants. This was carried out by digesting 2 gm of ground sample with a mixture of HNO_3 and H_2SO_4 solutions. The heavy metal concentrations were determined by Atomic Absorption Spectrophotometer while total Petroleum Hydrocarbon (TPH) was determined by Gas Chromatography.

MICROBIOLOGY

Surface and ground water, bottom sediments and soil samples were collected into sterile plastic bottles and polythene bags respectively, were stored in deep freezers and analysed in the laboratory within 48 hours of collection for microbial contents.

Heterotrophic bacterial counts

The total heterotrophic bacteria in both water and soil were enumerated using modified yeast extract agar (Cruickshank *et. al*., 1975). Bacteria isolates were identified according to the scheme of Buchanan and Gibbons (1974).

Determination of fungal content

The total fungal counts in the water and soil samples were determined using Emmons, Binford and Utz's modified Sabouraud Dextrose Agar (Cruickshank *et. al*., 1975). Isolated fungi were identified based on the associated spores and mycelia and their growth characteristics on the isolation medium.

Determination of percentage petroleum degrading bacteria and fungi

The petroleum degrading bacteria were enumerated on petroleum agar medium while chloramphenicol was added to those medium for the selective isolation and enumeration of petroleum degrading fungi. Any bacteria or fungi growing on these media were regarded as petroleum utilizers or degraders. The percentage of these counts to the total heterotrophic bacteria or fungal counts were then calculates to obtain the percentage petroleum degrading bacteria and fungi respectively in each sample.

SOCIO-CULTURAL PROGRAMME

Socio-economics

The principal objective of this socio-economic study is to identify and examine the specific effects of the waste pits and the borrow pits on the life of the communities within the study area . Two broad categories of methodologies were utilized in this study; ethnographic and socio-demographic survey method.

Ethnographic method

This method entails random administration of questionnaires, oral interviews and interaction with locals. In some settlements, where inhabitants did not speak or understand English language, the services of an interpreter was enlisted. The ethnographic method is ideal for studying social organization, institutions, economy and polity of the communities.

SOCIO-CULTURAL PROGRAMME

Socio-economics

The principal objective of this socio-economic study is to identify and examine the specific effects of the waste pits and the borrow pits on the life of the communities within the study area. Two broad categories of methodologies were utilized in this study; ethnographic and socio-demographic survey method.

Ethnographic method

This method entails random administration of questionnaires, oral interviews and interaction with locals . In some settlements, where inhabitants did not speak or understand English language, the services of an interpreter was enlisted. The ethnographic method is ideal for studying social organization, institutions, economy and polity of the communities.

Socio-demographic Survey

In studying the socio-demographic structure and dynamics of the localities, we concentrated on inquiring into the population structure (Age, sex and other compositional characteristics) and dynamics (birth, death, migration and marriage rates) of the inhabitants. We emphasizes the educational, occupational and work status pf the populations.

RESULTS AND DISCUSSION

Aquatic ecology

The results of the surface water bodies of the pits under investigation indicate tat the quality of some of the surface water bodies have been impacted by the facility operations. High levels of heavy metal, TPH, TDS, TSS, Conductivity, BOD and COD and low dissolved oxygen (DO) were recorded. However, the physico-chemical parameters of the ponds, rivers and creeks occurring around the study areas are normal for the freshwaters of the Niger Delta region of Nigeria. All the surface waters were devoid of significant hydrocarbon contents. The concentration of the heavy metals in surface waters was generally low. The villagers used the waters for domestic and recreational purposes.

TABLE1 -1
Physico-chemical characteristics of borrow pit surface water

Parameters	Sampling Points				
	A	B	C	D	E
pH	4.8	4.8	5.2	5.3	5.8
Temperature (^{0}C)	28	28	29	28	30
TDS (mg/L)	260	420	520	480	510
TSS (mg/L)	670	589	653	624	710
COD (mg/L)	65	52	67	62	65
Conductivity (µmho/cm)	525	840	1,045	965	1,020
Salinity mg/L)	45	38	48	45	37
DO (mg/L)	4	5	5	4	4
BOD (mg/L)	12	13	10	12	15
Sulphate (mg/L)	14.8	18.7	23	16.42	14.6
Bicarbonate (mg/L)	13.6	14.2	15.2	12.6	15
Nitrate (mg/L)	7.9	8.2	7.1	7.9	8.2
Zinc (mg/L)	1.2	1.1	1.2	0.98	0.99
Lead (mg/L)	0.98	0.75	0.72	0.56	0.97
Iron (mg/L)	1.5	1.4	1.3	1.7	1.1
Copper (mg/L)	0.87	0.75	0.66	0.87	0.55
Chromium (mg/L)	0.5	0.23	0.54	0.51	0.2

The physico-chemical and heavy metal characteristics of the ground water is within Federal Environmental Protection Agency/ Directorate of Petroleum Resources limits for drinking water. The groundwater yield is high level and less than 9m in depth. The groundwater is an important resource to the communities. It serves as drinking water and is used for domestic purposes.

Soil and sediment studies

Sediment to soil samples collected at surface and mid-depth smelt of high TPH concentration possibly due to drilling mud.

$$D = \frac{N_0}{v\,N_x} \qquad C^0 = \Sigma \frac{No\,(ni)^2}{N}$$

Where, Nx= No. of individuals in cells/station

TABLE1 -2
Physico-chemical characteristics of waste pit surface water

Parameters	Sampling Points				
	A	B	C	D	E
pH	5.2	4.8	5.8	6.2	5.5
Temperature (^{0}C)	29	30	29	28	30
TDS (mg/L)	320	480	520	610	425
TSS (mg/L)	541	432	654	780	756
COD (mg/L)	54	41	23	42	52
Conductivity (µmho/cm)	645	864	1,310	1.562	1,515
Salinity mg/L)	32	41	23	42	35
DO (mg/L)	4	3	5	4	3
BOD (mg/L)	14	12	15	16	13
Sulphate (mg/L)	16.4	24	18.2	16	17
Bicarbonate (mg/L)	14	16	14.2	15	12
Nitrate (mg/L)	8.9	10.7	9.87	.2	7.9
Zinc (mg/L)	1.3	1.5	0.99	0.97	0.97
Lead (mg/L)	1.1	1.3	0.76	0.64	0.61
Iron (mg/L)	1.3	1.5	0.89	0.78	0.66
Copper (mg/L)	0.99	0.87	0.74	0.71	0.67
Chromium (mg/L)	0.8	1.2	0.4	0.3	0.3

TABLE - 3
TPH levels of borrow pit soil samples

	Depth (m)				
	0-15	1	2	3	4
Sampling point	TPH levels (ppm)				
Control	24	32	45	52	28
A	10.879	11,201	6,764	876	56
B	654	10,566	4320	564	38
C	12,453	17,142	6,543	765	52
D	8,564	8,978	4531	720	45
E	7,230	8,210	3781	683	32

The soil texture ranges from sandy loam, silty loam, silty-clay loam and clay loam types in cultivated area, to silty and clayey types in the galloping swamp rainforests area of the study area. The soils are characteristics by high groundwater levels, seasonal water logging poor drainage and high organic matter content. The physico-chemical characteristics of the soils indicate that they re acidic and possess nutrient levels that range from moderate to poor. The liquid wastes generated during the normal operation/maintenance of the facilities may not have significantly impacted the soils. The levels of physico-chemical parameters like heavy metals hydrocarbon utilizing microbial studies confirm this observation.

TABLE - 4
Chemical composition of borrow pit soil samples

Parameters (ppm)	Sampling Points				
	A	B	C	D	E
Sulphate	63	72	54	48	45
Phosphate	34	42	3	30	30
Nitrate	52	58	50	48	45
Zinc	2.34	3.0	2.86	2.8	2.1
Lead	1.28	2.8	1.97	1.98	1.92
Iron	2.33	2.42	1.98	1.4	0.78
Copper	4.9	8.7	2.1	1.6	1.2
Chromium	2.2	5.9	2.96	2.67	2.21
Cadmium	7.2	7.8	6.4	6.2	7.1

TABLE - 5
TPH levels of waste pit soil samples

	Depth (m)				
	0-15	1	2	3	4
Sampling point	TPH levels (ppm)				
Control	24	32	4	552	28
A	9.786	10,342	4,502	520	42
B	5,640	6,701	4,382	480	32
C	9,601	10,985	5,428	348	37
D	5,250	6,781	4,531	450	28
E	4,560	3,890	3781	542	30

TABLE -6
Chemical composition of waste pit soil samples

Parameters	Sampling points				
(ppm)	A	B	C	D	E
Sulphate	52	61	42	35	27
Phosphate	28	34	26	24	18
Nitrate	48	52	31	27	20
Zinc	7.29	8.0	6.98	5.97	5.97
Lead	6.5	7.5	4.76	4.71	4.7
Iron	1.89	2.1	1.65	1.45	1.2
Copper	7.8	9.2	6.2	5.89	4.82
Chromium	3.4	4.4	3.1	2.95	2.2
Cadmium	6.8	7.4	6.3	5.67	7.2

Heavy Metals

Heavy metals levels were all close to background values. However, there were slightly elevated levels of Pb at some of the sampling points. The maximum

values detected in the borrow pit for Zn, Pb, Cu, Cr and Cd were 3.0, 2.8, 8.7, 5.9 and 7.8 ppm respectively. While for the Waste pit the values were 8.0, 7.5, 9.2, 4.4 and 7.4 ppm for Fe, Zn, Pb, Cu, Cr and Cd, Respectively. The high values obtained for specific locations inside the pits might be due to the presence of drilling muds. There was no discernible trend in either the lateral or vertical distribution of the heavy metals at most of the stations.

Total Petroleum Hydrocarbons

Borrow pit

The maximum TPH recorded was 17,142 ppm with average of 12,680. The relatively high levels of TPH might probably be due to the dumping of drilling muds.

Water pit

The maximum TPH recorded was 23, 522 ppm with an average of 18,678 over the study period.

Borehold Sediments

Borehole sediment samples TPH values obtained were relatively low (<500 ppm). Vertical distribution studies also shows that high TPH levels> 2000 ppm did not extend below the 3m mark.

Distribution of TPH in the samples

Analysis of the lateral spread of TPH in the pits did not show any discernible trend, in most cases the contaminants were concentrated at the edges of the pit. Some of the factors that might affect the spatial/lateral distribution of TPH in the pits are age of the pit and dumping of clean excavated soils. Also, sedimentation and erosional processes in the pits particularly during heavy rainfall can bring about changes in the direction of flow pits particularly during heavy rainfall can bring about changes In the direction of flow velocities which tend to push freshly dumped hydrocarbons towards the edges.

The vertical distribution of TPH in he soils and sediments generally show a clear stratification, with the highest concentrations in the shallowest depth fractions (0,1,2m). Significantly high levels of TPH (>3000 ppm) in the pits are limited to the 2.0 m depth mark. However, during remedial actions it is always necessary to excavate down to 3 m below the soil or sediment.

To check for migration of contaminants outside the pits, samples were collected at 1,2,3 and 4m distances away from the pits. Levels of TPH in the samples collected at these points did not show any significant difference from background values.

ECOLOGICAL PROGRAMME

Sub-surface species distribution and abundance is low due to low light penetration resulting in low levels of photoxidation and primary productivity.

Phytoplankton

The results of the phytoplankton (fig. 1) shows a total of 60 x 10^6 cells/m^3 in the Borrow pit and 184 x 10^6 cells/m^3 in the waste pit. The phytoplanktons were observed to belong to 3 divisions, *Bacillariphyta, Chlorophyta and Cyanophyta.* The Bacillariophyta, was more in total abundance in the waste pit (107 x 10^6 cells/m^3) than the borrow pit, (36 x 10^6 cells/m^3) and it dominated the other two divisions, Chlorophyta and Cyanophyta with abundance of 71 x 10^6 cells/ m3, 13 x 10^6 cells/ m^3 and 6 x 10 10^6 cells/m^3, 11 x 10^6 cells/m^3 respectively in waste pit and borrow pit.

The diatoms (*Bacillariophyta*) were all members of Pennales, mainly *Eunotiaceae*, *Pinnulariaceae*, and *Nitzachiaceae*. Other families such as Cymbellaceae, Fragillariaceae and Naviculaceae were represented by one or two taxa each.

The *Chlorophytes* were mainly chlorococcuhunicola comprising 41.5% of the *Chlorophyta* Division. The genera with high number of taxa were Cosmarium (4) and scenedesmus (5). *Closterium, Docidium, microateries, sphaercystis* were not represented by not more than two taxa each. Among the diatoms, Frogillaria had a very wide distribution among the stations. Among the *Cyanophyta*, the most widely distributed phytoplankton was Oscillatoria sp.

The diatoms are usually the dominant species in drier tropical regions of Africa. These are followed by *Cyanophyta* and rarely Desmids (Compere and Lltis, 1983). The *Cyanophyta* or blue green algae are known to thrive in rich nutrient or eutrophic condition. The high diversity of Desmids may be due to low mineral nutrients and low alkalinity (Lind, 1967: Islam and Haroon, 1985, Kadiri, 1988). Moderate levels of Calcium in water may also account for profusion of Desmids (Lind, 1968).

The species diversity with a total of 35 taxa is good. This might probably be due to the low nutrient level couples with the specific ability of the phytoplankter to utilize the limiting nutrients Obeng-Asamoa et. al. 1980; Ogawa and Ichimura, 1984). The results are typical and reflective of the trend in tropical waters within the African sub-regions where the most diverse algal classes are unquestionably the *Chlorophyta* (Woodhead end Tweed, 1958; John, 1986; Kadiri, 1993).

Zooplankton

Out of the four divisions of Zooplankton (fig. 2) the Copepod was more in total abundance with 1864 x 10^6 cells/m^3 In the Borrow pit than other divisions. This was followed by Cladocera with 350 x 10^6 cells.m3 in the waste pit.

The numbers of taxa as well as the density of Zooplankton were relatively high. All zooplankton groups (*Copepoda, Ostracoda, Cladodera and Rotidesa* were represented at the pits. Ostracods were almost ubiquitous, while Mesocyclops (*Cladoceraps*) were prominent.

The zooplankton species encountered in this study were all cosmopolitan species earlier reported in Nigeia (Egborge et. al., 1994; Ogbeibu and Egborge, 1995; Ogbiebu et. al., 1996: Ogbiebu , 1997). The spatial distribution of zoo-

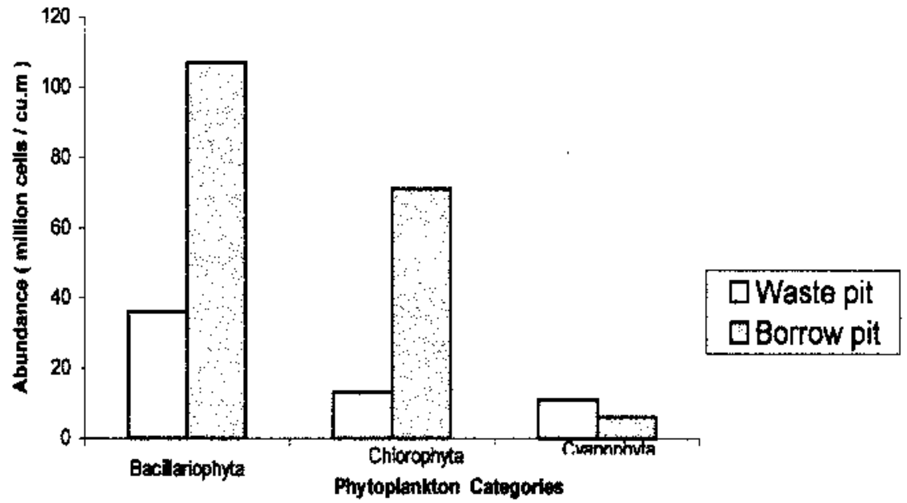

Fig. 1 - Phytoplankton distribution and composition in waste and borrow pits

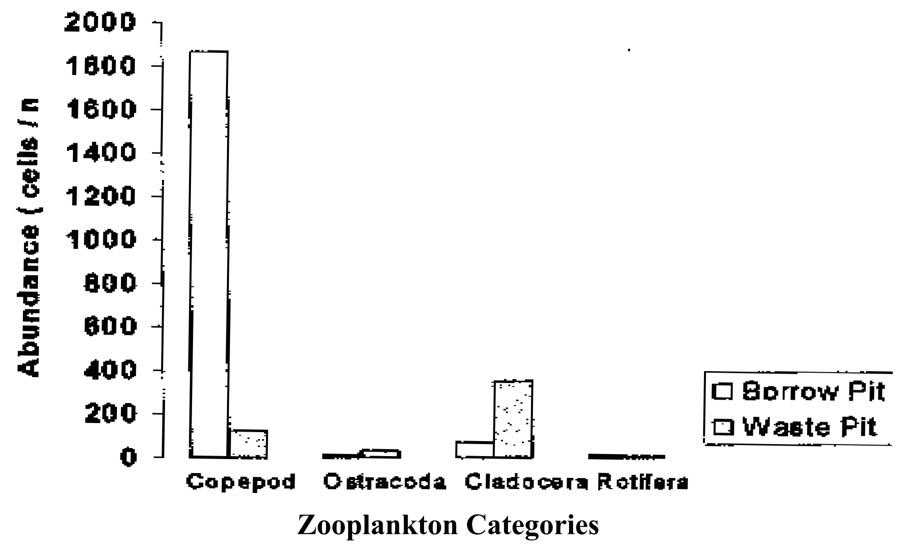

Fig. 1 - Zooplankton abundance and categories in borrow and waste pits

plankton is governed mainly by changes in water quality, food availability and presence of aquatic macrophytes (Ogbeibu, 1998).

There was however no significant difference (p>0.05) in the abundance of the phytoplanktons and zooplanktons in the Borrow pit and Waste pits in the study. The observed differences may have come from other unforeseen environmental variables.

Benthic fauna

A very diverse assemblage of 35 benthic fauna, comprising the *Annelida* (2), *Coleptera* (&), *Diptera* (10), *Ephemeroptera* (4), *Hemiptera* (1), *Odonata* (8), *Mollusca* (2) and tadpoles were identified in this study.

Macrobenthic fauna, because of their relatively sessile nature, ahs been used widely as Bioindicators of pollution. The study area presented a picture of rich diversity of fauna, and remarkable dominated by notable pollution indicators such as Dero spp., *Tubifex*, *Limnodrilus hoffmeistei*, *Chironomus fractilous*, C. transvaalensis, Culex and some donate nymphs like Anax and Tramea. These organisms, by their presence in high densities, reflect conditions of high organic pollution. One would conclude that generally, these pits have attained stabilization phase in their ecological development over time, and have now become conducive habitats for aquatic organisms.

VEGETATION

Classification and characterization

A total of twenty-six (26) plant species were recorded in the waste and borrows pits. Forty-six per cent of the plants consist of grasses; eight per cent were sedges, while the others were Forbes. Forty-six per cent of the plants were hydrophytes. The commonest hydrophytes include Fuirena umbellate, Echinochloa crus-pavonis and Nymphae lotus.

The pits were colonized by luxuriant population of aquatic macrophytes. Nymphae lotus is the only floating- leaved aquatic plant recoded. All the other macrophytes are emergent types.

Biomass and plant population density

There is large variation in the values of the biomass recorded. The highest (250 gm-^{2}) was obtained for the weed Panicum maximum while the lowest value (57 gm-2) was recorded for Cyperus iria. The biomass values (table 9) are a refection of the plant form, age and substrate nutrient level. Plants growing in nutrient rich substrate typically have luxuriant growth, which is reflected in the biomass.

The growth of a plant may however be limited if a toxic element is present in the substrate. The emergent macrophytes and terrestrial plants typically have higher biomass than submerged of floating plants. Farmlands and a little swamp forest surround the study sites. The plant with the highest density (1467 plants/hectare) is Manihot esculenta. The lowest value (50 plants/ hectare) was recorded for Bambusa vulgari (Table 3.4.3). There are small plantations of Hevea brasilensis 9rubber) around the study area. The bush fallows are rich in Oil Palm (Elaeis guineensis) which is a multi-purpose tree crop.

Pockets of galloping seasonal swamp forest occur around the facility area. In areas where land have been cleared and left fallow for a long time, grasses bush fallow ad secondary types of vegetation are observed.

The pathological studies indicate that the diseases observed on the leaves

of crops/plants are not unusal either in nature r severity. There is no evidence of endemic vegetation problems resulting from the waste and borrow pits in the area.

TABLE - 9
Mean Biomass of the commonest plants

Sr/No.	Taxon		Biomass (g/m^2)
1.	Cyperus iria		57±12
2.	Sparobolus pyramdlais	120±17	
3.	Ludwiga decurrens		86±10
4.	Scleria Verucosa	97±26	
5.	Imperata cylindrical		110±1 5
6.	Pancum laxum		95±30
7.	Nymohaea lotus	120±15	
8.	Panicum maximum		250±14
9.	Rhynchospora corymbosa	96±18	
10.	Panicum repends	165±13	

TABLE- 10
Population Density of key economic plants

Sr/No	Taxon	Density (No. of Stem/Hectare)
1.	Hevea brasiliensis	520±34
2.	Elasies quineensis	402±15
3.	Bambusa vulgaris	50±2
4.	Manihot esuleuta	1467±91

Hydrology

The abundance of silty sands in the subsurface implies that the aquifer properties are poor leading to marginal yield. However, silty sands have reasonable hydraulic conductivity for contaminant transport. This is aggregates by the lack of near surface clay/clayey bodies which cold hinder downward percolation of contaminants. The field is within the same hydrogeological regime where the groundwater level is shallow (a few meters from the surface).

Lithostratigraphic Analysis

The soils from the borehole samples were generally brown and yellow brown at shallow depths (3m). Close to the water table the soil became increasingly grey in colour. At the surface the soils are rich in organic material causing sometimes dark-brown to black colouring. Lithostratigraphic sections across the 3 boreholes showed varied proportions of topsoil, clayey sand, clay, sandy clay and sand.

Socio-economic study

In specific term the study focused on the influence on the existing demographic, structure, economic and income generating activities as well as the general quality of the people. The impacts on archaological, historical and cultural resources were also examined.

Settlement and population description

There is no ordered settlement pattern in the area, however, settlement are essentially in lineal/clustered structure with low density population. The largest settlement in the study area is estimated at 80,000 people. Other villages near the area are very small settlements lf less than 5,000 people.

Both crop yield and income from farming were reported to be declining over the years, a trend which was unanimously attributed to the effect of Oil exploration and production in the area. Similarly decline in fishery resources including quantity and quality of fish catch were also reported by the community and thus they also attributed to the effect of Oil pollution. The general consensus among the communities is that the operations of oil companies in the area have worsened their economic fortunes. They argued that although the presence of oil companies has helped to generate some paid employment, these are usually very few and limited to the employment of short-term unskilled workers.

The main reason adduced by the communities for the declined in crop yield, fish resources and income thereof is as a result of land taken by oil companies for construction of various facilities (flow lines, well heads, flow stations etc) including waste pits and borrow pits. The result is a decline in the average size of farmland per household.

Determination of the sources, transport mechanisms, exposure pathways and target receptors for contaminants

These were determined using the exposure evaluation flow chart of site investigation stage of Risked ased Corrective action procedure for petroleum release sites developed by the American Society for Testing and Materials (ASTM, 1994).

The primary sources of high levels of the contaminants identified in this study (i.e. hydrocarbons and heavy metals) were found to be drilling muds, production operations and oil leak/ spills from wellhead and station maintenance. Residents, sensitive habitats (vegetation, surface waters) soil and groundwater were the major targets and receptors of these pollutants.

CONCLUSION AND RECOMMENDATION ON REMEDIAL OPTIONS TO BE ADOPTED IN CLEAN UP

Introduction

There are several remedial options proposed for contaminated soils and sediments. However, a preliminary treatment process for both the water and excavated soil should be carried out. This preliminary treatment processes and recommended remedial treatment options for the contaminated waters and soils/sediments are mentioned.

Contaminated surface waters

Preliminary treatment

Before treatment the contaminated water will have to be first piped into an equlisation lined earthen basin or surface lagoon.

From here, the water will be mechanically mixed and the floating oil skimmed off. The effluent will then be pumped out for treatment. However, if contaminant concentrations in the waters are low e.g. if TPH levels are less than 10 ppm he waters can be discharges directly into a surface water body.

Treatment of contaminated waters

The following methods are recommended for treatment of contaminated surface waters :

(i) Aquacell wastewater plant

In this system, the wastewater is allowed to flow through a pair of 4 aquacell units contiguously linked. Into these units will be inoculated some formulation of hydrocarbon degrader and nutritionally versatile micro-organisms in synergism with toxicity tolerant macrophytes.

While the micro-organisms breakdown the hydrocarbon and complex pollutants into end precursors, the macrophytes absorb same as nutrient source. The major source of power in this system is Solar Energy. The macrophytes employed have the ability to absorb and metabolise heavy metals without eliciting any form of toxicity. Thus making this option an ideal candidate for the wastewater treatment.

The treated water us further polished through a biofilm spongy mesophyl and further through an ecobiofilm mesh for colloid removal and odour stripping. The final discharge in this system will be free of pathogens, organics, petroleum hydrocarbons and heavy metals. The treated eater will then be discharged trough an open drain channel constructed with wolverton interjections.

Chemical treatment

In this process, the wastewater will be piped into a primary treatment unit, which has a gritz for particular and solids removal. Commercial surfactants are injected which helps in the surface emulsification of the oils thus exposing same to higher bacterial enzymatic action. The emulsion can also be skimmed and transferred into pans and inoculates with extra-cellular bio-surfactants and oil degrading bacteria.

From the oil treatment tank, the water passed unto an aerator, which will further buoy all the oil molecules to the surface for skimming. The water is further pumped into a clarifier or sedimentation basin and allowed a sufficient residency time before transfer into the sand filtration unit and eventually into a chlorine injection chamber before final discharge into the effluent pathway that will empty into a nearby water body.

Biological treatment

In this method, water holding tanks of 3-6 mm thickness properly brazed with angle iron are employed. The tanks are usually 5m (7 x 5 x 1) m3 capacity connected to each other through a control valve. These tanks are a set o 4 parallel tanks receiving the effluent from a 10,000 gallons overhead tank. Into these tanks will be inoculated bacterial isolates that have high enzymatic activity, the bacteria will derive nutrients from the introduced biostimulants while oxygen is supplied through compressor aeration. The bacteria will take up all the pollutants including the petroleum hydrocarbon as nutrient source.

This process will proceed through a set of 4 tanks and then made to undergo polishing through a biologically activated filtration units for minerals, colloids and metals removal. The final treated water will then be discharged into the effluent pathway foe eventual; discharge standard compliance. The treated water can be re-circulated for continuous treatment.

Contaminated soil and sediments

Preliminary treatment

Hydraulic sand winning or mechanical excavation of the soils from the recommended area. Proper storage and mixing of these soils in an engineered dump site with drainage and leachate collection system.

Treatment of soils

The following methods are recommended for treatment of contaminated soils/sediments;

(i) Bio-catalytic Remediation

In this method, excavated soils are collected and dumped into a lined surface for dewatering. The dumped soil will be pulverized, dewatered to 20% moisture content with the incorporation of additives such as, mineral slats and fertilizers with effective pH adjustments, base saturation and bio-augmentation of te soil with bacteria specific for hydrocarbon degradation and heavy metals chelation.

Hydro-catalytic stripping

This involves passing all the excavated soils through a conveyor delivery system into hot water silos which undergoes an automated rotation of 1,5000 rpm with a 3 minutes resting time followed by a subnatant elution or supernatant syphone which will undergo repeated hydro-stripping until the final soil quality meets the required 30 ppm.

Land farming options

The soil mixed properly with mixed soil from a pristine location to reduce the hydrocarbon concentrations to optional levels. The soil is then broadcasted on a natural forest soil rich with debris which is lined pit or polythene lining. The soil is constantly aerated and water sprinkled on it. The soil will undergo natural treatment and then hydrocarbon tolerant plants lime the basidiomycetes could then be planted on the soil.

Depending on the results of the tissue analysis, the said plants could either

be consumed or crushed and employed as organic biomass for soil enrichment or for the return of barren soils into permanent productivity. The harvested plants will also be good candidate for soil conditioning.

Block making (solidification)

In this method, the harvested soil is discharges into a lines holding basin and allowed to sun dry. Licheate monitoring is very critical. Soils from the waste pits and borrow pits will then be properly mixed. Into the mixture will be added cement and sharp sand at a ratio of 5:1:1. The mixture can then be moulded into blocks which can be employed in the construction of bond walls, drain lines with proper surface lining as well as for drain slaps. They can also be sued for access restriction. However, leaching tests need to be carried put prior to the application of this option.

Slurry phase remediation

This is a liquid solid contact system achieved usually in a closed reactor or open pit. The contaminated soils will be suspended in a slurry and mixed to maximize mass transfer between inoculated microbes and electron acceptor, inorganic and organic components of the soil. Oxygen will then be supplies either through compressors, spargers or floating/submerged aerators followed by mechanical mixing. Single-batch or sequence-batch reactors exist. In sequence batch reactors, the soil will be added gradually and after several mixing at a given retention time, the decanted slurry will flow through the trapping system while the clean soil remains at the base, the oil will be trapped.

The reactors may be mobile above ground takes or lined in-situ lagoons. The settled soil can then be excavated, dewatered and applied in land farming. The liquid component can then be trucked and discharged into saver pits.

REFERENCE

APHA. 1989. *Standard method for the examinations of water and waste waters*. 17th ed. publishers: American public health association; American water works association and water pollution control federation.

ASTM. 1994. Emergency standard guide for risk based corrective action applied at petroleum release sites. (American society for testing and materials, Philadelphia), *ASTM ED* . p. 38-94.

Awobajo, S. 1987. On the environmental impact assessment of the eleme petrochemicals complex in proceedings of the 1985 int. seminar on the petroleum industry and the Nigeria environment, Lagos, *NNPC*. p. 2435-254.

Avbovbo, A.A. 1978. Tertiary lithostratigraphy of the Niger Delta, *AAPG Bull*. 26, p. 268-274.

Bray, R.H. and Kurtz, L.T. 1945. Determination of total organic and available forms of phosphorus in soils. *Soil Sci*. 59: 39-45.

Bremmer, J.M. 1965. Total nitrogen in C.A. Block (ed.) *Methods of soil analysis*. Apst 3. *Agron*. 9 : 891-901. AM. Soc. of Agron. 9 : 891-901. Madison. Wisc.

Buchanan, R.E. and N.E. Gibbons (eds), 1974. *Bergey's manual of determinative bacteriology*. Stl. edn. The Williams and Milkins Coy. Baltimore.

Chapman, S.B. 1976. *Methods in plant ecology*. Blackwell scientific pub., Oxford. p. 35.

Cruickshank, R.J.P. Duguid, R.P., Manion and R.H.A. Swain, 1975. *Medical microbiology* 12th edn., Vol (II) Churchill living stone London.

Ekundayo, A., A.B.M. Egborge and F.I. Opute, 1989. Report of ecological baseline studies of *NUGU N.W.* Location. shell petroleum dev.co. Nigeria ltd.

Ewer, D.W. and J.B. Hall, 1978. *Ecological biology 2*. The inter-relations of organism. Longmans Ltd.

FEPA, 1991. *National interim guidelines and standard for industrial effluents, gaseous emissions and hazardous wastes management in Nigeria*. FEPA, Abuja.

Greweling. T. and M. Peech, 1964. Chemical soil tests. *Cornell Univ. Bul.* 30 : 23-24.

Hutchinoson, J. and J.M. Dalziel, 1958. *Flora of west tropical Africa*, 2nd Ed. crown agents, London.

Koefoed, O. 1979. *Geosounding principles*. Elsevier publ. co. Amsterdam.

Kang B.T. 1984. Potassium and magnesium responses of cassava grow in Ultisol in southern Nigeria. *Fertilizers Res.* 5 : 403-410.

Leopold, L.B., Clarke, F.E. Hanshaw, B.B. and Balsely, Jr. 1971. A procedure for evaluating environmental impacts. *Geological Survey Circular* 645. government printing office, Washington DC. p. 13.

Murphy J. and J. P. Riley, 1962. A modified single solution methods for the determination of Phosphate in natural *Water. Annal. Chem. Acta.* 27 : 31-36.

Odemerho, F.O. and Awunudiogba A. 1995. *Environmental degradation and violent community conflicts in the oil producing area of the Niger Delta of Nigeria*: Underlying causes and policy options, Memeography, Department of Geography and Regional Planning, University of Benin.

Odu, C.T.I., Esuruoso, O.F., Nwoboshi, L.C. and Ogunwale, J.A. 1985. *Environmental study of the Nigerian agrip oil company operational areas*. Nigeria agrip oil company ltd., Lagos.

Ojo, 1972. *The climates of West Africa*. Hienman books limited, Ibadan.

Okafor, F.C. 1985. Measuring rural development in Nigeria : the place of social Indicators. *Social Indicators Research.* 16 : 69-76.

Okafor, F.C. 1986. The adaptive strategies of small holders in parts of south-eastern Nigeria : implications for agricultural planning's *Journal of Rural studies.* (2) : p.2 117-126.

Onokerhoraye, 1986. Rural systems and planning. The geography and planning series of study notes, department of geography, university of Bennin.

Reyment, R.A. 1965. *Aspects of geology of Nigeria* . Ibadan university press 145 p.

Short, K.C., and Stauble A.J. 1967. Outline of geology of Niger delta. *American association of petroleum geologists. Bull.* 51: 761-779.

Sobulo, R.A., Fayemi, A.A. and Agboola, A. 1977. Application of soil and analysis to nutrition of tomatoes in S.E. Nigeria. *Act hort.* 53 : 235-249.

Telford, W., Geldart, L., Sherrif, R., and Keys, J. 1976. *Applied geophysics* Cambridge University press, New York.

Todd, D.K. 1980. Groundwater hydrology (2nd Ed.) J. Wiley and Sons, NY. 535 p.

Udo, E.J. and Ogunwale, J.A. 1986. *Laboratory manual for the analysis of soil, plant and water samples.*p. 164.

Viets, F.C. and Lindsay, W.L. 1973. Testing soils for Zn, Cu, Mn and Fe. In : *Soil testing and plant analysis*. (Eds. L.M. Walsh & J.D. Bexton). *Soil Sci. Soc. Am. Inc.* Madison W1.

Zohdy, A. 1989. A new method for the automatic interpretation of Schlumberger and Wenner sounding curves. *Geophysics*. 54 : 245-253.