Thesis

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Assessment of Environmental Impact of Petroleum Activities in Port Harcourt and environs

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ASSESSMENT OF ENVIRONMENTAL IMPACT OF PETROLEUM ACTIVITIES IN PORT HARCOURT AND ENVIRONS

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CERTIFICATION

Mr. Prince Ndubuisi Chinaka Olemeforo, a postgraduate student in the Department of Geography, specializing in Environmental Management, has satisfactorily completed the requirements for course and research work for the degree of Master of Science in Environmental Management. The work embodied in this thesis is original and has not been submitted in part or full for any other diploma or degree of this or any other University.

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DEDICATION

This project is dedicated to my ever faithful LORD And SAVIOUR, JESUS CHRIST - The unceasing SOURCE of my life and Spirit, my ROCK and my strength, my hope and my inspiration, in WHOM only I will put my trust evermore.

Amen.

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LIST OF ABBREVIATIONS

BH	Borehole
Fig	Figure
VES	Vertical Electrical Sounding
M	Metre
^{o}C	Degree Centigrade
%	Percentage
Mg	Milligramme
PPM	Parts per million
Na	Sodium
Ca	Calcium
Mg	Magnesium
Fe	Iron
Mn	Manganese
N	Nitrogen
S	Sulphur
O_2	Oxygen
pH	Hydrogen iron concentration
Cu	Copper
Co	Cobalt
Mo	Molybdenum
Zn	Zinc
Hg	Mercury
Cd	Cadmium
H_2S	Hydrogen Sulphite
Ag	Silver
V	Volume
SPDC	Shell Petroleum Development Company
Cr	Chromium
Ni	Nickel
Cm	Centimeter
E.C.	Electrical Conductivity
Uohm/CM	Micro-ohm per centimeter
Ml	Milligram

N	Nitrogen
g	gramme
Nm	Nannometer
Meq	Milligram equivalent
Mins	Minutes
hrs	Hours
L^{-1}	per litre
M^{-1}	per metre
Zed	Secchi disc transparency depth
$MgC/M^3/hr$	Milligram Carbon per Cubic meter per hour
Mg/L	Milligram per liter
PSu	Primary Sampling Unit
AM	Apres midi or (in the morning)
BOD	Biochemical oxygen demand
THC	Total hydro Carbon
ND	Not detectable
Mg Kg^{-1} dry wt	Milligram per kilogram dry weight
PHNT	Port Harcourt North Transect
PHST	Port Harcourt South Transect
$PHNW_1T$	Port Harcourt North West First Transect
$PHNW_2T$	Port Harcourt North West Second Transect
$PHNE_1T$	Port Harcourt North East First Transect
$PHNE_2T$	Port Harcourt Nort East Second Transect
Sp	Species
As	Aspergillius
Fm	Fusarium
Pm	Penicillium
Pe	Pythium
Ka	Rhizoctoma
Ks	Rhizopus
Ta	Trichoderma
Vm	Verticellium
ha	Hectare
PDA	Potato Dextrose Agar.

ABSTRACT

In this research project, we assessed the environmental impact of petroleum activities in Port Harcourt and environs. The broad-based objective of the study was to undertake a comprehensive ecological impact assessment study to establish through physico-chemical, biological and socio-economic studies, the pollution levels if any, associated with oil production within the six oil producing fields of the area namely; Elelenwa, Apara, Edubu, Korokoro, Alakiri and Oloibiri fields. Another objective of the study was to evaluate the effects of oil pollution arising from petroleum production activities on the environmental components such as water, sediment, fauna, flora and soils of the impacted and non-impacted area.

In order to attain the objectives of the study, a careful consideration of the field observations and results of preliminary analysis was made along with relevant concepts of environmental pollution assessment. Subsequently, an experimental design which involved field sampling and laboratory analysis was formulated to ensure that, a valid comprehensive scientific evaluation of the magnitude of the temporal, and spatial levels of the oil pollution could be obtained.

Results from soil analysis demonstrated that there was evidence of an oil pollution but that this affected only the Port Harcourt North Transect at Elelenwa, and Port Harcourt South Transect at Oloibiri.

In these two affected transects, oil could be detected up-to the 150m and 250m from the spill point in both areas respectively, and up to a depth of 30cm. The values ranged between 8-860ppm which are far in excess of levels of oil from biogenic origin (5-50ppm). Also oil was detected from the chemical analysis of the sampled water boreholes in the area, but the levels were far below biogenic origin levels, ranging between 1.00ppm to 3.00ppm.

From Socio-economic studies, results indicate that Shell Petroleum, the only oil producer in the area has made a lot of positive impacts towards the development of the infrastructural base of the inhabitants, but her overall impact on the socio-economic well-being of the people had been more adverse than beneficial.

CHAPTER ONE
INTRODUCTION

1.1 STATEMENT OF THE RESEARCH PROBLEM

The over-emphasis on the economic exploitation of petroleum resources in Nigeria by petroleum industries to the neglect of the producing environment has made a negative impact on the same environment. Hence, evidence of significant deterioration of the ecological environment of the petroleum producing areas in Nigeria, abound (Odu, 1972; Imevbore, 1973; Ajakaiye, 1977; Inyang, 1978; Nwankwo, 1979; Oyefolu, and Awobajo, 1979; Oluwatimilehin, 1981; Lawanson and Imevbore, 1982).

On the other hand, significant positive developments are being undertaken by several petroleum producing companies in their various areas of operation, ranging from the provision of physical infra-structures and public utilities to the provision of financial aids for the general well-being of the inhabitants of their areas of operation (Shell Petroleum Development Company, 1988). Although these developments have contributed immensely to the upliftment of the standard of living of the inhabitants of their areas of operation, they have in no way provided the relevant remedy to the adverse impacts of petroleum discharges from oil producing fields on to their environment.

Although our main focus in this particular research is directed towards the Environmental impact assessment study of pollution from petroleum production in Port-Harcourt and environs, attempts have been made by some researchers to reveal not just the magnitude of environmental

impacts from petroleum discharges during production, but also including other segments of the petroleum industry, such as transportation, storage and processing (Nwankwo, 1979; Nwankwo and Irrechukwu, 1981). Hence, this has led to the classification of prtroleum pollution in Nigeria into two major categories namely, discharges from petroleum producing fields (mainly crude oil and gas) during production, which may or may not be accidental, and deliberate discharges of both solid and liquid wastes emanating from all sectors of the petroleum industry (Isichie, and Sanford, 1976; Imevbore, 1991).

Accordingly, therefore, significant ecological deterioration of the receiving environment has resulted, ranging from smothering of formerly luxuriant vegetation by oil spillages and the disappearance of other land inhabitants, to the contamination of surface and underground water systems (Odu, 1972, 1977a; Nwankwo and Irrechukwu, 1981). Consequently, due to the increasing impactation from petroleum discharges from oil producing fields onto the environment, there has been a corresponding decrease in the productiveness of land and water resources, particularly economic crops and fishery resources.

In other oil producing countries, such as Saudi Arabia and Indonesia, evidence from reliable data has exposed even in greater dimensions the extent of irreversible damages to wild-life due to petroleum discharges onto the environment (Spooner, 1970; Baker et al, 1981).

In Nigeria, mangrove plants have disappeared in some areas without any signs of rejuvenation (Olu, 1977a and b, 1978a). Soils steadily contaminated by petroleum show no signs of recovery. Consequently, vast tracts of agricultural land have been laid waste, thus becoming unproductive.

The result is great hardship for the inhabitants who become impoverished and deprived. Their economic production dwindle with corresponding social disorganization due to migration and forced relocation. And, although significant revenue and foreign exchange come daily from petroleum exploitation, its hidden long-term and sometimes irreversible impacts could easily outweigh the economic value if adequate attention is not given to the environment.

Accordingly, due to the stated problem, we deem it relevant to embark upon this research to assess the environmental impact of petroleum activities, in Port-Harcourt and environs, with particular reference to production (oil-field production) activities.

1.2 DEFINITION OF BASIC TERMS

"Environment" has been defined as an embodiment of conditions or circumstances which influence the rate and course of economic, social and political behaviour (United Nations, 1972). In common usage, the term "environment" is usually associated with natural environment, which ecompasses soil, water, air, vegetation and mineral resources. It should, however, also include the man-made, socio-economic environment such as physical and social infrastructures, since no productive activity occurs in an environment devoid of a politico-socio-economic framework (Titilola and Igben, 1992).

On the other hand, "Environmental Pollution," has been defined as, the unfavourable alteration of our surroundings, through direct or indirect effects of changes in energy patterns, radiation levels, chemical and physical constitution and abundances of organizms (Hodges, 1977). These changes may affect humans directly or through their supplies of water and of agricultural and other biological products, their physical objects or possessions, or their opportunities for recreation and appreciation for nature.

1.3 OBJECTIVES AND AIMS OF THE RESEARCH

This environmental impact assessment study is undertaken with the overall objective to:

Establish through physico-chemical, biological and socio-economic studies, the pollution levels associated with oil production facilities within Port Harcourt and Environs. Secondly, it is undertaken to evaluate the effects of environmental pollution arising from "Petroleum Production" activities on the environmental components such as water (Surface and groundwater), sediment, fauna, flora, and soils of the impacted and non-impacted area.

In order to attain the above set objectives of the study, the following aims were given specific consideration:

(a) Assessment of the general ecology of the area and adjoining terrestrial, aquatic habitats, and groundwater statuses (regimes).

(b) Determination of the concentration of crude oil and associated heavy metal pollutants such as (Nickel - Ni, Venadium - V, Lead - Pb, Chromium - Cr, Copper - Cu, Cadmium - Cd, Mercury - Hg, Manganese - Mn, Zinc - Zn, and Iron - Fe) at the different sampling points in the area with other physico-chemical measurements.

(c) Identifying the main cause of vegetation damage to determine measures to rehabilitate the environment as well as to prevent future occurrence, and definning in appropriate terms the morphological sequence and physical settings of the area to reveal oil spill impact relationship if any, with the socio-economic dependence and land use of the area.

1.4 THEORETICAL FRAMEWORK

In the selection of our basic analytical framework, we employed the basic principles of the ecosystem concept, while utilizing the "Checklist methodology" in most of our assessment of the problem. Nevertheless, before making the choice of our assessment methodology, we have attempted a brief review and evaluation of current EIA methodologies in use so as to reveal the degree of their individual relevance to our present study.

THE ECOSYSTEM CONCEPT

The term ecosystem was first coined in 1935 by Tansley, in an attempt to characterize the immense complexity and holistic character of the natural world. According to Tansley (1935), the term "ecosystem" includes not only the organisms, but also the whole complex of physical factors forming what we call the environment. Lindemann (1942), defined ecosystem in a more rigorous manner as a system composed of physical-chemical-biological processes active within a space-time unit of any magnitude, while Odum (1959), defined it as any area of nature that includes living organisms and non-living substances interacting to produce an exchange of materials between the living and non-living parts.

Concern over the status of the ecological component of EIAs led to a major Canadian study to formulate "guidelines" to improve the ecological contribution to EIA studies (Beanlands and Duinker, 1983). This has led to an increasing emphasis on the improvement of ecological aspects of EIA, and as can be envisaged in current works, the ecological assessment procedure can be the most important

for human welfare and environmental quality (Bisset 1988).

General Notions of the Ecosystem Concept:

Expatiating on the ecological views of Haekel and Reiter, (Duvigneaud, 1989), observed that environmental factors such as light, heat, water, mineral or organic substrates, determine biotopes, where living organisms of various kinds and numbers meet to form biosystems (mixtures of populations belonging to different species).

The plants, animals and micro-organisms in a biosystem develop associative links and form communities or biocenoses. For modern ecology, the integration of biocenoses to their environmental factors into functional ecosystems, where they are influenced by their environment and influence it themselves, is essential for the maintenance of life on earth. This is the holistic or holocoenotic concept (Bowonder, 1987).

Plants and animals - and thus biocenoses become metamorphosed, i.e. change their physiognomy under the influence of the environment. A biocenosis such as a forest exists in different formations according to its environment, e.g. an equatorial evergreen forest, or mediterranean broad-leafed forest, or the tropical monsoon decidious forest. Plant formations progress dynamically through a succession of pioneer and intermediate stages to a climax, which is a formation in a stationary equilibrium with the climate of the time. The climax may regress, due to natural or man-made disturbances, by forest fires, storms or parasites, organic and inorganic pollution and the succession starts all over again.

Ecosystem Dynamics: Reactions to Stress Due to Natural or Man-made Disturbances

In nature an ecosystem can be subjected to energy-linked disturbances storms, fires, droughts, abnormal cold, heat etc. - liable to modify its development (Toynbee, 1971). What is a detrimental stress at one level of the ecosystem can be beneficial at another; for example, periodic fire in a steppe or a mediterranean forest is a stress for many organisms which will be injured or killed, but not for the ecosystem which is adapted to fire and could not persist without it.

Natural stress is mainly acute, i.e. periodical, and ecosystems have adapted themselves to it either by a high resistance, or through redundancy (replacement of sensitive species by better adapted ones), or by a resilience which allows them to reconstruct themselves in a short time (Jansen, 1988).

In industrial society, man-made stress on the contrary, is often chronic, i.e. continuous, and linked to a chemical pollution unknown in the original ecosystem (Alsopp, 1972; Rappoport, 1974). Ecosystems under stress, however, show a tendency to modify their normal functioning: respiration increases, thus productivity decreases, and geochemical fluxes increase while biological cycles are hampered (Vernadsky, 1945).

Depending on the level of pollution, the ecosystem passes through a series of damage stages, from insignificant to collapse resulting in the definitive loss of its self-repair potential.

Accordingly, based on the logical relevance of the ecosystem concept to this research project, we employed it as our basic framework for our analysis. However, the ecosystem concept alone is inadequate for our present work, this is due to the fact that the scope of most environmental impact studies go beyond ecological considerations. Accordingly, the ecological procedure alone, may not adequately sensitize or reveal the hidden consequences of an oil spill impact, especially as may be envisaged within the human populations of affected communities. And this inadequacy may lead to weak conclusions and recommendation of inappropriate management strategies for the problem. Therefore, it becomes relevant that we complement this deficiency with an appropriate impact assessment methodology that would take care of this weakness.

BRIEF REVIEW AND EVALUATION OF ENVIRONMENTAL IMPACT ASSESSMENT METHODOLOGIES

Although there is a large number of EIA methods and/or models which have been developed and used in EIA, the variety is more apparent than real. Nearly all methods are examples or variants of general types which have specific organizing principles in common. These types are checklists, matrices, networks, overlays and models (Bisset, 1988). The extent to which particular methods are used in actual EIA studies varies considerably due to the suitability of the methods to particular EIA studies. A recent survey of EIA methods used in the USA shows the relative frequency of method used among a sample of 372 people involved in EIA works (Table 1).

TABLE 1: The Use Made of Various EIA Methods In The US.

	Respondents
McHarg graphic overlay method	38
Metropolitan Landscape Planning Model	3
Goals Achievement Matrix	10
Surrogate Worth Tradeoff Method	1
USGS Matrix	25
Environmental Evaluation System - EES	7
Environmental Quality Evaluation Procedure - EQEP	6
Environmental Quality Assessment - EQA	8
Water Resources Assessment Methodology - WRAM	15
Wetland Evaluation System - WES	19
Network Analysis	21
Adaptive Environmental Assessment and Management	4
Habitat Evaluation Procedure - HEP (Fish and Wildlife)	75
Decision Analysis	9
Kane Simulation Model - KSM	1
Other	106

Source: (US. Advanced Studies in Science, Technology and Public Policy, 1982).

From Table 1, it can be seen that no particular method can be applied in all EIA studies, however, various forms of checklist are widely in use. They are represented in the table by the Environmental Evaluation System, the Environmental Quality Evaluation procedure, Environmental Quality Assessment, and the Water Resources Assessment Methodology.

BRIEF REVIEWS OF TWO METHODOLOGIES

Overlay Mapping Methodology:

The simple method of visually representing individual impacts and combinations of impacts has a number of advantages. The results from application of the overlay method are easily understood. Most importantly, it is an important method for showing the spatial distribution of impacts. With this information, it is relatively easy to relate individual impacts and the total aggregate impact of a project to human populations who might inhabit the localities affected. This allows the distribution of beneficial and adverse impacts to be determined (Munn, 1979).

However, there are a number of disadvantages to manual overlays. Firstly, the interpretation of more than 12 overlays at one time is often difficult. This means that only a limited number of impacts can be considered because each impact requires a separate transparency. And this constraint can only be overcome by the use of up-to-date topographical maps and air photographs, assisted by computer interpretations (O'Riordan, 1980). Experience with the use of overlay method indicates that it is only most useful in assessing alternative routes for linear developments, such as pipelines, highways and transmission lines.

Checklist Methodologies:

The term "checklist" covers a variety of methods having widely varying characteristics and degrees of complexity. However, most share one common feature, that is a list of environmental, social and economic factors which may be affected by a development or action (Wathern, 1988). A good checklist method is able to aid the identification of impacts and ensure that impacts are not overlooked (See Table 2).

There are 4 different, but related types of checklists, namely, descriptive checklists, scaling checklists, scaling-weighting checklists and questionnaire checklists. A significant feature of the checklist methodology is the emphasis placed upon the evaluation of all impacts both adverse and beneficial with the employment of relevant methodologies to assess the magnitude of impact on each environmental factor under consideration. And considering the ecological relevance of this methodology, we employed it in the achievement of our research objective.

TABLE 2: An Example of Checklist

PHYSICAL

1. Geology

1.1 Unique Features
1.2 Mineral Resources
1.3 Slope Stability/Rockfall
1.4 Depth to impermeable Layers
1.5 Subsidence
1.6 Consolidation
1.7 Weathering/Chemical Release
1.8 Tectonic Activity/Vulcanism

2. Soils

2.1 Slope Stability
2.2 Foundation Support
2.3 Shrink-Swell
2.4 Frosk Susceptibility
2.5 Liquifaction
2.6 Erodibility
2.7 Permeability

3. Special Land Features

3.1 Sanitary Landfill
3.2 Wetlands
3.3 Coastal Zones/Shorelines
3.4 Mine Dumps/Spoil Areas
3.5 Prime Agricultural Land

4. Water

4.1 Hydrologic balance
4.2 Ground-water
4.3 Ground-water Flow Direction
4.4 Depth to Water Table
4.5 Drainage/Chemical Form
4.6 Sedimentation
4.7 Impoundment Leakage and Slope Failure
4.8 Flooding
4.9 Water Quality

SOCIAL

8. Services

8.1 Educational Features
8.2 Employment
8.3 Commercial Features
8.4 Health Care and Social Services
8.5 Liquid Waster Disposal
8.6 Solid Waste Disposal
8.7 Water Supply
8.8 Storm Water Drainage
8.9 Police
8.10 Fire
8.11 Recreation
8.12 Transportation
8.13 Cultural Facilities

9. Safety

9.1 Structures
9.2 Materials
9.3 Site Hazards
9.4 Circulation Conflicts
9.5 Road Safety and Design
9.6 Ionizing Radiation

10. Physiological Well-Being

10.1 Noise
10.2 Vibration
10.3 Odour
10.4 Light
10.5 Temperature
10.6 Disease

11. Sense of Community

11.1 Community and Organization
11.2 Homogeneity and Diversity
11.3 Community Stability and Physical Characteristics

5. Biota

5.1 Plant and Animal Species
5.2 Vegetative Community
5.3 Diversity
5.4 Productivity
5.5 Nutrient Cycling

6. Climate and Air

6.1 Macro-climate Hazards
6.2 Forest and Range Fires
6.3 Heat Balance
6.4 Wind Alteration
6.5 Humidity and Precipitation
6.6 Generation and Dispersion of Contaminants
6.7 Shadow Effects

7. Energy

7.1 Energy Requirements
7.2 Conservation Measures
7.3 Environmental Significance

12. Psychological Well-Being

12.1 Physical Threat
12.2 Crowding
12.3 Nuisance

13. Visual Quality

13.1 Visual Content
13.2 Area and Structure Coherence
13.3 Apparent Access

14. Historic and Cultural Resources

14.1 Historic Structures
14.2 Archeological Sites and Structures

(Source: US Department of Housing and Urban Development (1975)

1.5 LITERATURE REVIEW

Man's impact on his environment goes back far beyond the beginning of history (Nicholson, 1970). As human numbers increased, people colonised new lands so that a larger and larger area was affected. Until modern times major influences exerted by man on the environment were almost all direct and concrete, such as burning and cutting forests, converting land to grazing areas or crop-growing, diverting streams and so forth (Sauer, 1956; Stewart, 1956). Indirect, unitended and unrecognised interferences were retatively insignificant.

However, with the advent of modern technology, the role of man on environmental change has been magnified (Commoner, 1969). Thus, technology, while creating a "better life" for man, has created more environmental change per capita, thereby escalating man's impact. Several workers with similar views, such as Evelyn (1969); Abbou (1972); Alsopp (1972); Doxiadis (1977); Krieps (1989); and Harrison (1990); however, have in addition elaborately discussed the complementary role of man and his technology in the world-wide environmental degradation.

Abbou (1972), has observed a good relationship between man, health and the environment - a relationship which he found to be clearest in the cities than in their pernipheries.

In his studies on the types of pollution and nuisances present in an urban environment and their consequences on the health of the inhabitants, he observed that people can be affected either by their environment or by the action of other people. He took the former as a direct action by the environment due to physico-chemical agents, (already released by man) such as ionising radiation, exhaust fumes, asbestos dust, carcinogenic substances, or climatic circumstances such as temperature, moisture and wind. Whereas the later (indirect pollution by man) can have a biological aspect, and which may be due to contagion by germs, parasites, lice, effects of food additives or of excesses of medicines.

However, with regards to this particular research, copious literature (from various researchers working in different parts of the world) on the environmental impacts of petroleum activities abound. In Europe and North America the following researchers, such as Wilson et al (1980); Schutt and Ellis (1985); Ashmore et al (1985); Pearce (1986); Hinrichsen (1988); McCormick (1989); have concentrated their research on the effect of pollution due to the wide range utilization of fossil fuels particularly petroleum fuels in various locations in Europe and North America. Similarly, Kinzelbach (1981); Perera (1982); Gennino and Shorrock (1982); Jernelov (1983); Sharma (1983); Sani (1983); Smil (1984); and Hardoy and Satterthwait (1985) have concentrated on the environmental impacts of petroleum pollution in some selected third-world countries.

Some of these countries include China, India, Malaysia, Brazil, South Korea, Mexico, Zambia, Kenya, Nigeria and South Africa.

In his research in China, with emphasis on the northern oil rich parts of the country, Jernelov (1983), stated that cities like Beijing and Lanzhov give cause for greatest concern due to their heavy concentrations of the country's largest oil refineries and petrochemical industries. He observed that, pollution from these industries has destroyed fruit trees, caused date plants to stop producing fruit and stopped pumpkings, from maturing.

Results from a joint project between the UN Environment Programme (UNEP) and SCOPE (a Committee of the International Council of Scientific Unions) conducted in 1980, using case studies from Nigeria, Bangladesh, Brazil, China, India and Venezuela, have implicated the large scale exploitation and utilization of petroleum resources in the significant increase of SO_x and NO_x in the environments of the countries listed.

On the other hand copious documented evidences on the environmental impacts of oil spillages abound (Yapp, 1972; Nelson-Smith, 1977; Munn, 1979; Adrian and Ingram, 1985; Trammier, 1991). And their deleterious impacts on the ecological environment of mostly oil producing countries, such as Nigeria, Saudi Arabia, Algeria, Kuwait, Venezuela, are fully documented. Tramier (1991), has observed a gradual but progressive destruction of ecological species in Kuwait since the end of the gulf war.

He particularly noted a large scale disappearance of the rare aquatic desert mangroves, tortoises, crabs, crustaceans etc., some of which have been completely eradicated by huge oil spillages and gas flares.

In Nigeria, the following researchers such as Odu (1972, 1973, 1977 a,b,c, 1978 a,b,); Imevbore (1973, 1991); Ikichei and Sanford (1976); Nwoboshi (1977); Adedipe and Nwoboshi (1977); Ajakaiye (1977); Inyang (1978, 1980); Oluwatimilehin (1981); Baker (1981); Lawanson and Imevbore (1987); Titilola and Igben (1992); have in various dimensions treated the varying adverse impacts of petroleum activities in Nigeria.

Odu (1972), observed that petroleum oil exerts adverse effects on plants indirectly (through the soil) by creating certain conditions which make nutrients such as nitrogen and phosphorous, essential for plant growth unavailable to plants. Furthermore, the adverse condition created by oil in the soil make some toxic nutrients more available to plants. Oil contamination of the soil thus results in the soil becoming unsuitable for crop growth. And depending on the degree of contamination, the soil may remain unsuitable for crop growth for months or years until the oil is degraded to tolerable levels. In the same vein, on aquatic life Imevbore (1973), observed that free oil and emulsions may coat and destroy algae and plankton, interfer with photosynthesis, kill fish through injection of poisonous soluble fractions, such as phenols and sulphides.

The same compounds may kill aquatic birds and oysters, while the accumulation of petroleum sludge may prevent the germination and growth of plants.

Also Oteri (1981), has fully investigated the impacts on ground-water resulting from the 1980 Funiwa - 5 oil well blowout in which more than 400,000 barrels of crude oil was spilled. He discovered that of the 5 villages affected, Fishtown was the only community whose ground-water was heavily polluted. Consequently, the inhabitants have been forced to either relocate or seek for alternative domestic water supply, since their only source of potable water supply has been permanently polluted.

Accordingly, there is copious evidence to show that petroleum industries operating in Nigeria have actually adversely impacted on their operating environments. And although the list of previous works on this particular problem is large, no attempts have been made by previous researchers to undertake a comprehensive and balanced view of the problem. Essentially, most of the previous works have concentrated only on the negative impacts of petroleum activities in Nigeria, while neglecting the crucial beneficial impacts of petroleum exploitation, consequently, this has resulted to a lopsided evaluation of the problem at hand. And this inadequacy of previous works in evaluating the problem may stem from the type of methodologies employed in the assessment of the problem which tended to reveal only a handful of negative impacts without making provisions for the assessment of benaficial impacts.

And as rightly observed by Drobny and Smith (1973), a good environmental impact assessment methodology, should represent more than five of the following basic requirements for an impact assessment:

(1) An impact assessment method should be comprehensive;

(2) Flexible;

(3) Capable of detecting project generated impacts;

(4) Should be objective;

(5) Should ensure input of expertise;

(6) Utilize the state of the art;

(7) Employ explicitly defined criteria;

(8) Provide for assessment of impact magnitude;

(9) Provide for overall assessment of total impacts;

(10) Detect environmentally sensitive areas.

Therefore, it is against this background of unbalanced and non-comprehensive assessment of the environmental impacts of petroleum activities, that we embarked upon this particular research to assess the environmental impact of petroleum activities in Port Harcourt and environs.

1.6 THE STUDY AREA

Location and Size:

Port Harcourt metropolis is the administrative capital of Rivers State of Nigeria. The city which also includes the Local government council, does not have an operating oil producing field, however, its immediate surroundings does. Therefore most of our studies have concentrated on the immediate outlying environments constituting 3 local government areas, namely: Obio/Akpor LGA flanking the North and North-western part of Port Harcourt, Tai/Eleme LGA flanking the North-eastern and South-eastern part, and Okirika LGA, flanking the Southern and South-western part (Figure 1).

Taking a closer look at figure one, our study area lies approximately between latitudes $4^{0}30'$ and $5^{0}00'$N and longitudes $6^{0}50'$ and $7^{0}20'$E of the Equator and Greenwich Meridian respectively. Our investigation was focused on the 6 oil producing fields in the area, two from each of the 3 local government areas. The selected fields are as follows; (1) Elelenwa and Apara fields - Obio/Akpor L.G.A., (2) Ebubu and Korokoro fields - Tai/Eleme, and (3) Alakiri and Olubiri fields - Okrika L.G.A.

Relief and Physical Setting:

The study area which has several attributes of a typical Niger Delta environment, is divided into two closely related environments, except that one has a little drier environment than the other. Both are located within the freshwater zone of the Niger Delta.

Three of the oil producing communities, namely; Elelenwa, Apara, and Ebubu (a little more Northern than Port Harcourt city) are located in more or less drier environments than the others located in the southern part of Port Harcourt city, which include Korokoro, Olaibiri and Alakiri. Udo (1981), has elaborately discussed on the characteristics of this fresh-water zone of the Niger Delta. According to Udo, this zone is the largest and the most important physical division of the area. The northern part of this zone has a greater silt and clay foundation and is more susceptible to yearly inundation by river floods. Most water channels in this fresh water zone are bordered by natural leveos (of heights between 20 - 30 mtrs) which are of great topographical interest and of great economic importance to the local people. Also, the bulk of the petroleum deposits in the Niger Delta are contained within this zone.

Within this zone may be found a good number of fairly high lands, constituting mainly of laminated clays, silts and fine sands (Assez, 1976). These elevated uplands, which do not exceed 50m., provide sites on which settlements like Elelenwa, Apara, and Ebubu are built.

The predominant economic activity of the inhabitants of the area is mainly farming/fishing and boat-making for those living within the wetter southern part, and combined fishing/farming for those living within the upland drier area.

The exceptional amount of rainfall within the area, ranging between 2000mm to over 3000/yr., has created considerable problems to settlement and land use, since most parts of the area are affected by seasonal swamps and muddy water most parts of every year. Economic crops such as yams, cassava and maize, for this reason are, therefore, restricted to the drier parts of the area.

Geology:

The area is generally overlain by thick layers of alluvium and clayey-silt, which are underlain by a complex of coarse and medium grained sandstone beds (Murat, 1970; Merki, 1970). Within this area at several locations, the sedimentary deposits are mostly heterogeneous in nature, being composed of sandstones, shales, calkareous shales, marl and fossiliferous limestone. Differential subsidence along faults that develop here produce broad anticlinal folds which provide structural traps for petroleum.

1.7 RESEARCH METHODOLOGY

All our methodological procedures including sampling and laboratory procedures are fully discussed in Chapter three. However, to achieve the objectives of our study the underlisted activities were undertaken namely - field work, laboratory analysis of samples, interpretation and report writing.

(a) Apart from two reconnaissance surveys, two field studies were undertaken during the rainy and dry season periods. Such field studies lasted for an average period of eight days. The two reconnaissance surveys were undertaken between February 8 - 15, 1992 for the Dry Season, and August 15 - 22, 1992 for the Wet Season. Thereafter, two field studies were undertaken between February 13 - 20, 1993, for the Dry Season, and August 14 - 21 for the Wet Season. It was after these last two field studies that our various sample analyses were undertaken. Finally, 2 complementary field studies were undertaken between November, 27 - December, 1, 1993, and February, 1994.

(b) Laboratory analyses of samples collected during field studies were subsequently undertaken to include physico-chemical analyses of soil, pit profiles, sediment, water heavy/trace metal/ion, underground water sample; biological analyses, and physical analyses of surface and sub-surface waters. The extent of the above analyses, are as specified in Chapter 3.

1.8 SCOPE OF THE STUDY

The study is divided into 5 chapters as follows: Chapter One which is the "Introduction," took care of the statement of the research problem, the objectives of the study, the theoretical framework, the literature review, the study area and a summary of the research methodology.

In Chapter Two, we tried to assess the sources of Oil pollution, and attempted an evaluation of their probable effects on their immediate environments. In Chapter three, we tried to describe our materials of study and as well as explain our methods and procedure of study. This also included our field sampling rationale and laboratory analytical procedures - which included soil studies, vegetation studies, aquatic studies, primary productivity studies (for both micro/macro-biology and fish biology), Sediment studies, Hydrological and Geophysical studies, and socio-economic studies.

Chapter four took care of the results from our laboratory analyses on soils (soil samples), vegetation samples, aquatic samples, microbiological samples, fish biology, sediment samples, hydrogeophysical and hydrogeochemical samples and socio-economic studies. This also included discussions on all the variables listed above.

Finally, we concluded our work in Chapter five, where we made a list of our recommendations for further studies on the problem.

CHAPTER TWO

ASSESSMENT OF PETROLEUM POLLUTION SOURCES AND EVALUATION OF THEIR PROBABLE EFFECTS ON THE IMMEDIATE ENVIRONMENT

2.1 DEFINITION AND DESCRIPTION OF THE NATURE OF MAJOR POLLUTANTS

Petroleum and/or oil can only be adequately defined in terms of their chemical nature and physical properties. Petroleum is a mixture of hydrocarbons. Several hydrocarbons occur in nature. In crude oils, the major components belong to only two hydrocarbon series namely, the parafins or methane series and the naphthene series. The methane series consists of straight-chain-hydrocarbons i.e. the n-alkanes which may occur as gases e.g. methane, liquids e.g. n-pentane or solid paraffin wax e.g. n-hexadecane. The naphthene series comprises of alicyclic hydrocarbons or cycloparaffins. They may occur as gases e.g. cyclopropane, liquids e.g. cyclopentane. Cyclopentane (C_5H_{10}) and Cyclohexane (C_6H_{12}) are the predominant components in most crude oils. Apart from the methane and naphthene series, crude oils and natural gas have some non-hydrocarbon components. The commonly encountered non-hydrocarbon components are heterocompounds namely nitrogen, oxygen and sulphur (S-N-O) compounds and organocompounds of some heavy metals mainly nickel and venadium.

A small fraction of the suphur in crude oil is in the form of elemental sulphur (in solution) or of Hydrogen sulphide, while a significant proportion is bonded with carbon in organic combination principally as polyaromatic constituents of the crude. Nitrogen in crude oil is associated mainly with the asphalt contant.

Compounds of oxygen with definite structures which occur in crude oils are acids and phenols. The order of increasing abundance of the heterocompounds is sulphur Nitrogen Oxygen.

2.2 SOURCES OF OIL POLLUTION

Pollution from oil and/or petroleum ranges from a massive single spillage as from a fractured pipeline to the lesser but apparently repetitive losses which usually arise from careless handling at flow station, to such continuous but often small scale sources as an undetected leak or an oil contaminated flow of waste water.

Information from various field investigations undertaken for this research coupled with documented data reveal additional sources of oil pollution as drilling/waste pit failures, sabotage/instrument theft, well-head failures and marine/terminal operational accidents. From Table 3, it can be observed that over 60% of the cummulative annual totals of crude oil spilled from all sources in the study area emanated alone from flow station operations (c) and from Flow stations Engineering Faults (C.).

Another important source of crude oil spillage requiring our attention from the Table, is that from Line or pipeline failure (A), which incidentally occupies the second pre-eminent position. Over 25% of all crude oil spillages in our study area can be attributed to this source alone. However, a prominent causative factor worthy of mention is sabotage/instrument theft (F), which occupies the third position in terms of the total number of spills in the area, but incidentaly it has cummulative volumes share of less than 2½%.

Table 3: Sources and Causes of Crude Oil Spills in Port Harcourt and Environs (1985 - 1993)

Causes	1985				1986				1987				1988				1989				1990				1991				1992				1993				Overall Total
	Number of Spills	%	Net Vol. Bbls.	%	Number of Spills	%	Net Vol. Bbls.	%	Number of Spills	%	Net Vol. Bbls.	%	Number of Spills	%	Net Vol. Bbls.	%	Number of Spills	%	Net Vol. Bbls.	%	Number of Spills	%	Net Vol. Bbls.	%	Number of Spills	%	Net Vol. Bbls.	%	Number of Spills	%	Net Vol. Bbls.	%	Number of Spills	%	Net Vol. Bbls.	%	1985-1993
A Line Failure	2	100	350	100	2	50	1150	58	3	75	321	34	4	57	4022	81	3	28	7608	36.1	-	-	-	-	7	78	725	15	2	12	200	19	3	27	105	11	14481
B Drilling/W. Fits	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
C Flow Stations Operations	-	-	-	-	2	50	830	42	1	25	620	66	2	29	32	1	4	36	13955	62.1	1	50	5700	59	-	-	-	-	5	29	240	22	2	18	190	20	20667
D Marine Operations	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
E Sabotage/Theft	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	18	80	0.4	-	-	-	-	-	-	-	-	9	53	580	54	4	36	635	68	1295
F Well Heads	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	18	520	56	520
G Flow Station/ Inc. Faults	-	-	-	-	-	-	-	-	-	-	-	-	1	14	900	18	2	18	300	1.4	1	50	4000	41	2	22	4020	85	1	6	50	5	-	-	-	-	9270
Total	2	100	350	100	4	100	1980	100	4	100	941	100	7	100	4954	100	11	100	21043	100	2	100	9700	100	9	100	4745	100	17	100	1070	100	11	100	930	100	46233

Source: Field Work 1993.

2.3 EVALUATION AND DESCRIPTION OF THEIR PROBABLE EFFECTS

Quantification of the effects of oil pollution is difficult becausa the origin and composition vary significantly. The effects may also be dependent on the nature of the spillage, the history of the spillage, the volume of the spillage, the nature of the flora or fauna, as well as the nature of the locality. Crude oil when spilled on the environment can ultimately, be degraded by chemical, physical or biological processes either with or without human interference and become innocuous but in the process, they may lead to diminishing the richness and variety of the environment and ultimately the quality of human life and life span (Jorgensen, 1976).

The biodegradation of petroleum is a slow process which depends largely on the size and composition of the constituent hydrocarbon molecules. Short chain alkanes rapidly evaporate and are toxic to several micro-organisms. Intermediate chain alkanes undergo rapid biodegradation. Branch chain alkanes rarely undergo degradation but when they do, the process is rather very slow. The rates of biodegradation in all component alkanes is higher than those in aromatic and alicyclic compounds. For the latter, the rate of biodegradation increases with the incorporation of long aliphatic side chains. Biodegradation of petroleum is controlled by such factors as available nutrients notably phosphorous and Nitrogen, temperature, the nature of the petroleum, the dissolved oxygen concentration and the micro-organisms present (Harrison, 1990).

Crude oil can affect macro-vegetation very adversely, causing great economic losses. Usually poor primary productivity of plants due to inhibition or damage of the chlorophyll as well as inhibition of the gerneral metabolic activity of the plant such as translocation and transpiration occurs. In addition, yellowing of leaves, defoliation, coating of surfaces of plants is also observed. Some factors which determine the nature and intensity of the effect of polluting crude oil on vegetation include nature of the soil, topography, nature of the crude oil, temperature, hydrography, age and physiological state of the plant (Mason, 1981).

The nature of groundwater pollution is determined by the geology, mineral composition and pedology of the underlying rock and soil which the water flows through before reaching the desired aquifers. Groundwater quality depends on its chemical, physical and bacteriological statuses. Most groundwaters contain organic and inorganic compounds as well as heavy metals which affect their quality. Inorganic compounds usually encountered in groundwaters are carbon-dioxide, Hydrogen Sulphide, Sulphur dioxide, iron oxide etc. Elements commonly encountered include aluminium, calcium, dissolved oxygen, iron, magnessium, manganese, potassium, sodium, silicon etc. The levels of these elements and/or compounds are affected by the ground-water temperature. The heavy metals usually present in groundwaters are cadmium, chromium, cyanide, lead and mercury. The depth of groundwaters generally affect the level of dissolved substances.

Deeper groundwaters contain more dissolved substances than shallow forms. With increased temperatures, the concentration of these dissolved substances are significantly increased due to higher solubility (Rhoades, 1971).

Crude oil is made up of many fractions and the toxicity of the various fractions increases along the series paraffins, naphthalenes and olefins to aromatic hydrocarbon. Within each series of hydrocarbon the smaller molecules are more toxic than the larger and higher ones; parafins are almost non-toxic.

Oil Spills present hazardous effects not only on fishing and recreational activities but also on those organisms which live in water or depend entirely on life in the aquatic environment (Green and Trett, 1989). Damage to sea birds has brought oil pollution to the attention of the public. Oil spill has been shown to alter the community structure by decreasing the amount of energy available for maintenance, growth and reproduction. Cameron, (1985) investigated the effect of crude oil and salinity stress on the metabolism of two common filter feeding musads Mytilus edulis and Modiolus demissus. Carbon budgets were calculated for each species under a variety of combinations of oil content and salinity. Both reduced salinity and the presence of crude oil tend to reduce the net carbon flux for each species. Although similar responses to oil were shown by each species M. edulis appeared to be slightly more resistant to oil than Modiolus demissus.

The susceptibility to poisoning by dispersants is related to the nature of the cuticle of the animal i.e. whether it is lipopholic or lipophilic. Crustaceans being more susceptible to hydrocarbon based dispersants has lipophilic cuticle.

Generally toxicity of crude oil to marine animals is less than that of refined oil and its products. This is because refined oils contain larger quantities of moderately volatile aromatic compounds that are more toxic than the persistent water soluble components of petroleum oil (Dudley, 1976). It is also reported that Kuwait oil is less toxic to Eurypanopeus depressus than what is obtained by exposing R. harrisii to No.2 Fuel Oil (Spooner, 1970). Exposure of Daphnia Sp. to naphthalene produced immediate behavioural changes. In animals exposed to concentration greater than 5 mgl^{-1} the movement of the second antennae ceased resulting in the organism coming to rest on the bottom. Survivors showed persistent sluggish behaviour compared with the control after 24hrs. The organism often recovered, however, after the toxicant concentration fell to non-detectable levels.

Toluene which is also a major component of water soluble fraction of refined oil, has been employed in the toxicity studies. Cot, (1976), investigated the acute toxicity of Toluene to three age groups of Fat head Minnows Pimephales Promelas. In the experiment designed to determine the 96-h LC50 and LOEC (lowest observed effect concentration) of Toluene, 1 day post hatch protolarvae and

and 30 day old fish was used to determine the LOEC. They reported that embryos are more resistant to toxic effect of toluene than larval or adult forms. This they attributed to either the lower metabolic rate of the embryos or the result of toluene being sequested on the lipid-rich yolk, thus reducing the rate at which it is metabolized.

Information on this aspect is rather scanty on the patterns of adjustment and regulation to oil pollution by some animals, however, Baker et al; (1981), reported that although marine crustaceans do rapidly accumulate petroleum hydrocarbons, and in particular the aromatic fractions from water, they also release the accumulated compounds very rapidly even during continued exposure. This has been attributed to the induction of microsomal mixed function oxidase system capable of the metabolic detoxification of aromatic hydsocarbons. This system has been identified in adult crabs, and in spot shrimp Pardalus Platyceros (Lipsey and Malcom, 1981). Induction of such a system allows surviving crabs to reach a new lower steady state tissue burden of hydrocarbons during continued exposure.

Since the production of Crude oil is often associated with several toxic inorganic compounds and/or elements, such as mercury and other heavy metallic compounds, which serve as production catalysts, the possibility of these harmful substances being introducedinto the immediate environments is very likely during oil spillages.

It has been found that fossil fuel accounted for an annual release into the environment of about 5×10^3 metric tonnes of mercury at the present rate of utilization. Some of these atmospheric mercury eventually find their way into the fresh-water system. The mercury in the aquatic environment is associated very largely with the particulate phase, either in suspension or as bottom sediment (Matis, 1971). Transformation of heavy metals by micro organisms was first observed by Williams and Wilder, (1971) when they found that sediment from an aquarium methylated mercury from mercuric chloride. This methylation did not occur with heat sterilized sediments. The sediments from Swedish lakes and rivers were found to form both methyl and dimethyl mercury from the ionic species. The methylation did not occur under anaerobic condition, presumably because the presence of hydrogen sulphide caused the precipitation of the mercury as sulphide. Studies on the biochemical mechnism of methylation, has shown that both dimethyl and methyl mercury were formed and that trivalent cobalt was implicated in the methylation process as methyl donor (Storach and Vaz, 1983). Mercury will thus circulate in the aquatic biosphere in the methylated form, but in the sediment it is more likely to be inorganically found either as the sulphide or in iron complexes.

The effect of crude oil spills on the terrestrial environment, especially on soils, plants and animals has been adequately described in Chapter One.

CHAPTER THREE

MATERIALS AND METHODS OF STUDY

3.1 FIELD SAMPLING RATIONALE AND LABORATORY ANALYTICAL PROCEDURES

SAMPLING POINTS

The methods adopted for the field sampling/collection of data was based on the standard procedures for ecological assessment studies. At appropriate sampling points, representative samples were collected for water bore-hole, socio-economic, vegetation and soil. The entire study area was, based on the results of the preliminary surveys, subsequently divided into 6 distinct ecological micro units by utilizing the locations of the 6 flow stations of six oil producing fields in the study area. They are as follows, Port Harcourt north transect - Elelenwa (PHNT), Port Harcourt north-west transect (PHNWT) at Apara, Port Harcourt north-east transect (PHNET) at Ebubu, Port Harcourt South-east transect (PHSET) at Korokoro, Port Harcourt South-west transect (PHSWT) at Alakiri, and Port Harcourt South transect (PHST) at Olobiri.

From each of these stations, samples were collected as appropriate for water, soil, vegetation, hydrogeochemical/geophysical and Socio-economic evaluation.

SITE SURVEY

The site survey was carried out using standard survey instruments notably angules, bearings, compass, theodolite, tape, staff among others. The transects were set out, and cut. The transect lines were then levelled.

The transects were cut at minimum intervals of 50m and a maximum of 250m to cover a length of 1,000m and width of 1,000m from each sampling reference point.

Points of primary spillage were used as centre points, and were thus equidistant from the extreme points of the transects at the cardinal axes.

3.2 BIOCHEMICAL AND HYDROGEOLOGICAL ANALYSES

3.2.1 Soil And Vegetation Studies

The soil studies involved three aspects, namely, the field and laboratory procedures; estimation of the physico-chemical statuses and geomorphology, and evaluation of the soil micro-biological status. From the latter, information on the floral and faunal characteristics of the soil was obtained following appropriate laboratory analysis.

FIELD PROCEDURES

Soil Samples were collected from:

1. Random samples within the transects,
2. Systematic samples at intervals of 50m - 250m as appropriate,
3. From pit-profiles distributed to cover the entire sites and the control areas.

From 1 and 2 above, soil samples were collected at two depths namely, 0 - 12cm and 15 - 30cm. For 3 above, soil samples were collected at 0 - 15cm, 15 - 30cm and below 30cm usually 30 - 60cm. Additional soil samples were also collected at levels of differing soil colouration.

From each sampling location at least six soil samples were collected at points using a soil auger or trowel. The samples were subsequently bulked together to give one composite sample for any depth sampled. In determining the choice of sampling adequate care was taken to allow for the inherent variability of soil materials as spatial variability often exist over small areas. The bulking procedure for the soil samples was standardised by ensuring that samples collected were of equal volume and from the same soil depth.

On collection, soil samples were immediately transfered into polythene bags. The soil samples were subsequently stored in deep freezers pending analysis. Aeration of collected soil samples was minimised by ensuring that no air spaces were left in the bags during sealing.

LABORATORY PROCEDURES

1. Hydrogen-ion-Concentration (pH)

Soil pH was determined by the 1:1 Soil: water ratio method as described by Jackson (1970) using a multipolarographic meter, Horiba U-7 model. 10g soil sample was dissolved in 50ml distilled water and stirred at regular intervals of 5 minutes for 30 minutes. The pH of the suspension was measured by dipping the electrode into the suspension for 3 minutes for equilibration to be attained.

2. Electrical Conductivity

The electrical conductivity (E.C.) of the soil was measured using the filtrate for the pH measurement. To measure, the electrode of the Horiba U-7 model meter was dipped into the filterate in a small holding beaker and the reading taken after 3 minutes. The conductivity value was expressed in micro-ohms/cm (Uohm/cm).

3. Air Drying

The soil samples were air dried by thinly spreading the sample on newspapers in the laboratory which was well aerated. The soil was occasionally stirred to expose a fresh surface. Drying was completed after 48 hours at room temperature. Air dried samples were then sieved using a 2mm mesh size sieve. Soil aggregates larger than 2mm were gently crushed to break up aggregates to avoid shattering soft mineral particles that may be present.

4. Exchangeable Cations

2.5g of a well ground soil sample were shaken in a conical flask containing 25ml of neutral in ammonium acetate, for 30 minutes and filtered. From the filtrate the following cations were determined using a flame photometer:

Sodium ion (Na^+)

Potassium ion (K^+)

Calcium ion (Ca^+)

Also the follwing cations were determined from the above filterate using Atomic Absorption Spectrophotometer (AAS):

Magnesium ion (Mg^{++})

Manganese ion (Mn^{++})

iron (III) ion (Fe^{+++})

5. Organic Carbon

Organic carbon was determined after the wet combustion method of Walkley and Black (1934). 1.0g well ground soil sample was transferred into a 300ml capacity beaker and treated with 10ml of IN potassium dichromate to wet the samples. 20ml of concentrated sulphuric acid was immediately added to the wet mixture. The beaker and its contents were then rotated with care for 20 minutes. 200ml of distilled water was then added to the contents of the beaker. 25ml of 0.5N ferrous ammonium sulphate was added and titrated using 0.4N potassium permanganate under very strong light.

6. Total Nitrogen

1.0g of the soil sample was transfered to a digestion flask and 5 tablets of sodium sulphate, 3 tablets of selenium and 2ml copper sulphate solution were added. 40ml of analytical grade concentrated sulphuric acid was added and the contents were mixed and subsequently swirled gently. The resultant mixture was digested over a tecator block at 350°C until the digest turned greyish-white. The final mixture was then allowed to cool and washed into a distillation unit. The contents were made alkaline by adding 10% sodium hydroxide and then distilled into 25ml of boric acid indicator that had previously been pipetted into a conical flask. From the distillate, 75ml was measured into another conical flask and titrated using 0.11mlcl N.

Nitrogen content of the soil was calculated using the relationship:

$$\%N = \frac{M \times t \times 14 \times 100}{S} \qquad \text{Eqtn.(1)}$$

Where:

M = Molarity of the HCl

t = titre value

S = wt. of Soil used.

7. Ammonium Nitrate and Nitrate Nitrogen

Ammonium nitrate, and nitrate nitrogen were determined by shaking 5g of soil sample in a flask containing 50ml of IN potassium sulphate. Ammonium nitrogen was determined by nesslerization using aliquots of the soil extracts. Nitrite Nitrogen was determined by the Greiss-Ilosvay method in which alpha-napthylamine and sulphanilic acid were used. Nitrate nitrogen was determined by the phenoldisulphonic acid method as described by Machereth (1963).

8. Available Phosphorous

The phosphorous concentration of the soil was determined using the method of Jackson (1970). 2g of soil sample was transfered into a conical flask and 20ml of Bray P-I extraction solution (0.03N NH_4F and 0.25N HCL) added. The flask with its contents was stirred for 3 minutes and then filtered. 5mls of the filtrate was then pipetted into 25ml volumetric flask and made up the mark by the addition of 16ml distilled water and 4ml of ascorbic acid solution (0.056g ascorbic acid in 200ml molybdate-tartarate solution). The mixture was allowed to be stored for 20 minutes to ensure full colour development.

The above treatment was carried out for standard P stock solution for reference calibration curve. The absorbence was measured at 882nm on a spectronic 70 spectrophotometer.

9. Hydrocarbon Concentration

5g of the soil sample was transfered into a conical flask followed by the addition of 10ml of toluene. The mixture was then shaken and the absorbence of the oil extracted was measured at a wave-lenght of 420Mu using a spectrophotometer. The above treatment was carried out for standard hydrocarbon containing extractant for standard curve preparation. Using the standard curve the total hydrocarbon concentration was then determined.

10. Determination of Available Cations (Ca^{2+}, K^{+}, Na^{+}, Fe^{3+}, Mg^{2+}, Mn^{2+})

2.5g. of soil sample was transfered into a conical flask followed by an addition of 25ml of IN. Ammonium acetate (CH_3COONH_4). The misture was shaken for 45min. and the extract filtered into glass beakers. Aliquots of the filterate was used to determine the concentration of calcium, ion, Potassium ion, and Sodium ion by falme photometry. The concentration of Iron, Magnesium and Manganese was determined by using an atomic absorption spectrophotometer (AAS). Using Jackson's method, Jackson (1970), the concentration of the cations were calculated and expressed in parts per million (ppm) or milligramme equivalent per 100g soil (Meq/100g Soil).

11. Sulphate Concentration

The soil sample was ashed after pre-treatment. 5mg of the extract was transfered into a 30ml capacity beaker and 10ml of distilled water was added followed by gentle stirring using a glass rod. To the mixture, 10ml glycerol (I + I glycerol water) was rapidly added using a burette and stirred vigorously but without spilling any liquid with the glass rod for 20 seconds. The beaker was then transfered to a refrigerator and the temperature of the mixture brought down to $15^{o}C$. 2ml of Barium chloride was added followed by stirring for 20 seconds. The mixture was then allowed to stand for 30 mins. at room temperature $25^{o}C + 2^{o}C$. Standard solutions of sulphate were also prepared. The concentration of sulphate was then determined at a wave-lenght of 600nm using a spectrophotometer and standard reference of zero.

12. Phosphorous Concentration

Phosphorous Concentration was determined after cooling the extract to $15^{o}C$. The extract was then transfered into a conical flask and 20ml of Bray P-I extraction solution (0.03N NH_4F + 0.25N HCL) was added followed by gentle stirring for 3 mins. and then filtered.

13. Exchangeable Acidity

2.5g of soil sample was transferred into conical flask followed by the addition of 25ml of 1N Potassium chloride. The mixture was shaken for 20minutes and filtered. 10ml of the filterate was titrated using 0.10 IN sodium hydroxide using phenolphthalin as indicator after McKean (1965). The concentration of the exchangeable acidity was calculated and expressed as milliequivalent per 100g soil (Meq/100g soil).

14. Heavy Metals

2.5g of the sieved, air-dried soil sample was transfered into a 250cm^3 capacity conical flask. 25cm^3 of 2M analar grade nitric acid was added to the flask and mixture was shaken followed immediately by heating at 100^{o}C on a waterbath for 2hrs. The flask and its contents were then allowed to cool. 20cm^3 of distilled water was then added to the flask followed by shaking and filteration. The filtrate was decanted into a 100cm^3 conical flask followed by the addition of distilled water to make up the solution to the 100cm^3 mark. Standard solutions of the heavy metals containing 25% of 2M analar grade nitric acid were also prepared. The concentration of the heavy metals were then determined using an atomic absorption spectrophotometer.

15. Soil Microbiological Analysis

The estimation of the micro-organisms in the soil sample was investigated using the soil dilution plate method where serial dilutions of the soil sample in sterile distilled water were plated out using nutrient agar and incubating at $30^{o}C$ for 48 hours. 1g of the soil sample was transferred into a McCartney bottle, followed by the addition of 10ml sterile distilled water and shaking. The resulting soil suspension thus gave a dilution of 10^{-1}. 1ml of soil suspension was then transferred to another McCartney bottle containing 9ml sterile distilled water using a sterile micro-pipette. The suspension of the latter bottle was gently and carefully shaken to give a dilution of 10^{-2}. Using the same procedure, other serial dilutions were made up to a final dilution of 10^{-6}. Identification of bacterial components was after the method of Cowan (1974).

To enumerate the micro-organisms, 1ml. portion of the 10^{-6} dilution above was plated out on a nutrient medium of manitol extract agar and incubated aerobically at $26^{o}C + 2^{o}C$ for 3 days. The treatment was also replicated and counted.

To estimate the fungal organisms, 1ml portion of the 10^{-3} dilution obtained from the serial dilution above was transfered into MacCartney bottles containing 9ml of Molten Potato Dextrose Agar (PDA) to give a dilution of 10^{-4} and maintained at $43^{o}C + 2^{o}C$ in a water bath. To prevent the growth of bacteria, 0.1ml streptomycin solution was added to each bottle of agar containing the soil suspension.

Each bottle was carefully and gently rocked. The contents of the bottle was then transfered into sterile petridishes, and incubated for 3 days at $26^{o}C + 2^{o}C$. The developed fungal colonies were then identified and counted to give the fungal population. The treatment was also replicated.

Vegetation Studies

1. Biological Analysis

Vegetation samples were collected in triplicates for angiosperms, bryophytes, and pteridophytes from the study area and labelled accordingly. The smpling technique involved a combination of the random, systematic and stratified random sampling procedure. At each sampling point within the transects, the count Quadrat Technique in which quadrats of 20m x 20m dimention was used.

As much as possible, samples were identified in the field while unidentified samples were taken to the herbarium and subsequently identified.

Apart from vegetation identification;

(a) the dead and threatened vegetation was observed and probable causes of death noted.

(b) plant species usually the apparently dominant forms were collected for plant nutrient analysis.

(c) the pathological condition of the plants especially the economic ones was investigated such as the insect pests, bacteria, fungi and viral diseases.

(d) the girth at breast, height, density etc., were also investigated.

2. Chemical Analysis

Dry Ashing of Plant Tissue Material

Plant samples for chemical analysis were oven-dried at 70°C for 14 hrs. and homogenised. The homogenised samples were then dry-ashed. Dry ashing was effected using 1g of the homogenised sample which was transferred to a Silica dish and ashed for 2½ hrs. at 550°C in a muffle furnace. The ashed sample was cooled and dissolved in 5ml of 2N nitric acid. The resultant mixture was then filtered and made up to the 50 Cm^3 mark using distilled water.

3. Determination of Ca^{2+}, K^+, Na^+

From the filterate above, the concentration of Calcium, Potassium and Sodium was determined by flame photometry.

4. Chloride Cl^-

Plant samples were transferred into a conical flask followed by the addition of 5ml of 50% solution of magnesium nitrate and heated gently to dryness over a water bath. After the residue was treated, the concentration of chloride was then determined by titrating 5ml of the plant extract with 0.05ml silver nitrate solution, tetraborate (as pH buffer) and potassium chromate (as indicator) until a permanent reddish colour was developed.

5. Nitrogen

1.0g of the plant sample was transferred to a digestion flask and 6 tablets of sodium sulphate, 3 tablets of selenium and 2ml copper sulphate were added. 40ml of analytical grade concentrated sulphuric acid was added and the contents were mixed and subsequently swirled gently. The resultant mixture was digested over a tecator

block at 350°C until the digest turned greenish-white. The final mixture was then allowed to cool and washed into a distillation unit. The contents were made alkaline by adding 10% sodium hydroxide and then distilled into 25ml boric acid-indicator that had previously been pipetted into a conical flask. From the distillate, 75ml was measured into another conical flask and titrated using 0.1N potassium chloride. The percentage total nitrogen content of the plant sample was calculated using the relationship:

$$\%N = \frac{M \times t \times 14 \times 100}{p} \qquad (2)$$

Where M = molarity of the H Cl,

t = titre value

p = wt of plant sample used.

6. Sulphate Concentration

The plant sample was ashed after pre-treatment as in (2) above. 5mg of the plant extract was transferred into a 30ml capacity beaker and 10ml of distilled water was added followed by gentle stirring using a glass rod. To the mixture, 10ml glycerol (1 + 1 glycerol and water) was rapidly added using a burettle and stirred vigorously but without spilling any liquid with the glass rod for 20 seconds. The beaker was then transferred to a refrigerator and the temperature of the mixture brought down to 15°C. 2 ml of Barium Chloride was added followed by stirring for 20 seconds. The mixture was then allowed to stand for 30 minutes at room temperature 25°C + 2°C.

Standard solutions of sulphate were also prepared. The concentration of sulphate was then determined at a wave lenght of 600nm using a spectrophotometer and a standard reference of zero.

7. Phosphorous Concentration

Phosphorous concentration was determined as in (6) above except that after cooling to 15^{0}C, the extract was transferred into a conical flask and 20ml of Bray P-1 extraction solution (0.03N NH_4F + 0.25N HCl) was added followed by gentle stirring for 3 mins. and filtered. 5ml of the filtrate was then pipetted into 25ml of volumetric flask and made up the mark by the addition of 16ml distilled water and 4ml of ascorbic acid solution (0.56g ascorbic acid in 200ml molybdate-tartarate solution). The mixture was allowed to stand for 20 mins. to ensure full colour development. The above treatment except for (6) above was repeated out for standard P stock solution for reference calibration curve. The phosphorous concentration of the plant tissue was measured at 882nm on a spectronic 70 spectrophotometer.

3.2.2 Aquatic And Sediment Studies

1. Sampling Stations

Based on the results of the preliminary surveys and general observations in the study area, sampling points for aquatic studies were chosen as appropriate. From each of these sampling points, samples were collected which on analysis, yielded data for the aquatic parameters investigated.

Water Collection

Water samples for the determination of physical and chemical water characteristics were collected in triplicate without trapping air using standard water sampler of capacity 1 dm^{-3} at each depth and location.

The sample has a closing mechanism which can be opened and closed at various depth. The long axis of the water sampler is vertical when the opening and closing mechanisms are operated. At points of high water level, the sampler was weighted to enable it displace water more effectively and hence sink to lower depths. When the sampler reaches the desired depth of sampling, the plastic covers are opened and water enters through the short open tube. Simultaineously, air is discharged through the long open tube which extends above the bottle. The water in the sampler is transfered without contacting air to the analytical glass or plastic bottles by inserting a drain tube to the bottom of the bottle, filling it and allowing water to overflow for a few seconds.

2. Determination of Water Quality Characteristics

Water Temperature

Surface water temperatures were measured using either a mercury in glass thermometer, or polarographic temperature metre by direct immersion. The readings were taken 3 minutes after immersion.

For water from the sub-surface (lower depths), the thermometer was enclosed in a vertical position in the water sampler before it (the sampler) was lowered to be filled with water at the desired depth. After 5 minutes the sampler was quickly retrieved and the temperature read with the thermometer still in position. The HORIBA U-7 multi-polarographic meter was also used to measure temperature by direct immersion and the value displayed read off after 3 minutes.

3. Hydrogen Ion Concentration (pH)

Water pH or hydrogen ion concentration was determined in the field using electrometric pH metres - HORIBA U-7 model.

4. Secchi Transparency

Measurements of water transparency were made using a secchi disc of diameter 20cm. This was submerged on a graduated line into the water. The depth at which it disappeared from view as it was slowly lowered was noted as (X_1) and the depth at which it reappears again as it was pulled up was also noted as (X_2). A transparent ruler was then used to measure these depths. The average of these two depths in Cm was recorded as the transparency reading.

5. Coefficient of Light Extinction

This was determined using the relationship of secchi disc transparencies and the light extinction coefficient. The relationship based on empirical data of secchi depth, recommended by Idso and Gilbert (1974), is;

$$M^{-1} = \frac{1.7}{Zsd} \qquad (3)$$

Where Zsd = secchi disc transparency depth in metres

M^{-1} = Coefficient of light extinction

6. Electrical Conductivity

The electrical conductivity of water was estimated using a polarographic metre HORIBA U-7 model. Values were expressed in Siemens, (Ohm^{-1}) or Uohms.

7. Free Carbon Dioxide

100ml water sample was transferred into a conical flask without agitating the sample. 10 drops of phenolphthalein was added as indicator. If the sample turned pink, free carbon dioxide was recorded as 0.00ppm. If the sample remains clear, it was then titrated with N/44 sodium hydroxide from a burette until a weak pink colour developed for at least 30 seconds.

8. Dissolved Oxygen

This was determined by the modified Winkler - azide method (Lind, 1979; American Public Health Association, APHA; 1980). Water samples were fixed in the field with managanous sulphate, alkaline-azide solution and conc. sulphuric acid. Calculation was based on equation given below (Golterman, 1970).

$$\text{Dissolved Oxygen (mg/l)} = \frac{V(D) \times N(D) \times 8 \times 1000}{\text{Volume of Sample} - 2}$$

Where D = Sodium thiosulphate ($Na_2S_2O_3$) (4)

V = Volume of $Na_2S_2O_3$ used in titration

N = Normality of $Na_2S_2O_3$ (0.124N)

The result was expressed as % - saturation based on the equation given by Golterman (1970); Lind (1979).

$$\% - \text{Saturation} = \frac{\text{Oxygen Concentration mg/lx 100}}{\text{Solubility}} \quad (5)$$

Solubility was obtained from the standard solubility conversion table in which solubility of water at particular temperature is given (Golterman, 1970 ; Thomas and Chamberling, 1974).

For convenience, determination of dissolved oxygen at various depths during diurnal sampling was taken at the field using portable Horiba water checker, model U-7.

9. Phenolphthalein Alkalinity

100ml of water samples was transfered into 250ml Capacity Erlenmeyer flask and 2-4 drops of phenolphthalein indicator added. The sample was then titrated over a white slab against 0.02N ConC. Sulphuric acid until it turned clear. Titre volume of acid was multiplied by 10 to give phenolphthalein alkalinity.

10. Methyl Orange Alkalinity

To the solution (9) above, methyl orange indicator was added. The greenish-yellow solution, obtained was titrated with 0.02N. Conc. Sulphuric acid until the colour turned pink. Titre volume of acid obtained was multiplied by 10 to give methyl orange alkalinity.

11. Total Alkalinity

Total alkalinity was obtained by adding the titre volumes for phenolphthalein (9) and methyl orange (10) alkalinity. Value was then expressed in dm^{-3}.

12. Dissolved Organic Matter (D.O.M.)

9.5ml of N/100 potassium permanganate was added to 100ml water sample and boiled for 10 minutes. While hot, 15ml of 25% sulphuric acid was added; followed by 10ml of ammonium oxalate. The resulting colourless product was titrated with N/100 Potassium permanganate to pink end-point. Blank titration with distilled water was carried out. D.O.M. = (Titre value for water sample) - Titre value for blank x 3.14.

13. Biochemical Oxygen Demand ($B.O.D_5$)

Water samples were incubated for 5 days at $20^{o}C$ in the dark before titration for oxygen using the modified Winkler-azide method (A.P.H.A., 1980).

$B.O.D._5$ = Dissolved Oxygen on day 1 - Dissolved Oxygen on day 5 (mg/l).

14. Hardness

This was determined by diluting 25ml water sample to 50ml with distilled water. 1ml each of buffer and indicator solutions were addred, followed by 2 drops of Erichrome-black-T indicator. The resultant reddish solution was titrated with EDTA - titrant drop by drop until light-blue colour end point was observed. Calculation was based on the equation given by Lind (1979); and A.P.H.A. (1980).

$$\text{HARDNESS } (Mg/CCO_3) = \frac{\text{Ml. of titrant} \times 1000}{\text{ml. of Sample}} \qquad (6)$$

Analytical result was reported as"hardness (EDTA)"

15. Chloride

2 - 3 drops of potassium chromate was added to 100m. water sample and titrated against silver nitrate until a pale yellow colour was observed.

Chloride Mg/l = Volume of Silver nitrate used x 10.

Primary Productivity Studies

A. Collection of Water Samples for Incubation

Water samples for incubation of phytoplankton for the estimation of primary broductivity was collected as detailed for physical and chemical water characteristics.

B. Treatment of Water Samples

The water sample collected was siphoned into one dark bottle and three clear or light bottles of 250ml capacity. One of the contents of the light bottles was treated immediately with WINKLER'S reagents to fix the initial oxygen. The other light bottle was later analysed for the initial carbon dioxide content. The dark bottle and untreated light bottle were tied to a string and lowered to the depths from which they were originally collected. Suspension of the bottles was achieved using a nylon line held in position by an inflated rubber float. The bottles were run in triplicate over an incubation period of 4 hrs. (10.00 hrs. - 14.00 hrs.). At the end of the incubation periods, the dissolved oxygen was fixed using 1ml each of managanous chloride and alkaline iodide. Prior to fixing the oxygen, the temperature and pH were also measured. The carbon dioxide content was also determined.

C. Laboratory Procedure and Principle

The concentration of dissolved oxygen was estimated by the WINKLER method. The principle of the light and dark bottle method is that when samples of phytoplankton population in light and dark bottles are exposed, the initial concentration of dissolved oxygen (C_1) can be expected to fall to a lower value (C_2) in the dark bottles by respiration and to be changed to another value (C_3) in the light bottles according to the difference between photosynthetic production and respiratory consumption.

If other processes involving oxygen (e.g. photoxidative consumption) are absent or can be neglected, and if it is assumed that respiratory consumption is not altered by illumination, then the difference $(C_1 - C_3)$ represents the respiratory activity per unit volume over the time interval involved, the difference $(C_3 - C_1) + (C_1 - C_2) = (C_3 - C_2)$ the gross photosynthetic activity. Based on the above principles, estimates of gross photosynthesis are obtained directly from the difference in concentrations between the light and dark bottles.

1. Estimation of Primary Productivity

From the above;

C_1-C_2 or IB - DB = respiratory activity per unit volume per time interval.

C_3-C_1 or LB - IB = net photosynthetic activity per unit volume per time interval.

$C_3-C_1+C_1-C_2$ = C_3-C_2 or LB - IB + IB - DB = gross photosynthetic activity.

Where IB = Initial Bottle (7)

LB = Light Bottle

DB = Dark Bottle

The initial bottle values cancel each other and it is then possible to estimate gross photosynthetic activity directly from LB - IB as shown above. The method then estimate the gross photosynthesis thus:

Gross Photosynthesis = Net O_2 evolved + O_2 used in respiration.

To express the changes in oxygen in terms of carbon as carbon is both the initial material and the end product of synthesis and of respiration. The photosynthetic quotient (PQ) and respiratory quotient (RQ) are dimensionaless numbers indicating the relative amounts of oxygen and carbon involved in the processes of photosyn thesis and respiration:

$$PQ = \frac{O_2}{CO_2} = \frac{\text{Molecule of oxygen liberated during photosynthesis}}{\text{Molecules of Carbon dioxide assimilated}}$$

$$PQ = + \frac{CO_2}{O_2} = \frac{\text{Molecules of Carbon dioxide liberated during respiration}}{\text{Molecules of oxygen consumed}} \qquad (8)$$

$$\text{Gross Photosynthesis } (mgC/m^3/hr) = \frac{(O_2,LB) - (O_2,DB)\ .1\ (1000)}{(PQ).\ (t)}$$

$$\text{Net Photosynthesis } (mgC/m^3/hr) = \frac{(O_2,LB) - (O_2,LB).\ (1000)}{(PQ).\ (t)} \qquad (9)$$

$$\text{Respiration } (mgC/m^3/hr) = \frac{(O_2,\ IB) - (O_2,\ OB).\ (RQ).\ (1000)}{t}$$

Where t = hours of incubation

O_2 = oxygen in mg/k

2. Chlorophyll - a

The method used is as described by Vollenweider (1971); Lind (1979). 500ml of water samples were filtered through a 45mm diameter 11A - millipore fibre of 0.45 U pore size. Near the end of filteration, 1ml of 1% aqeous suspension of magnesium carbonate was added to prevent phaeophytinization (hardning) of pigments due to acid conditions. 25ml of 90% acetone was used for extraction in cool dark condition for about 24 hrs. Extraction was centrifuged to remove debris.

Chlorophyll absorption was measured spectrophotometrically in cells of 4cm at 665nm and 750nm and value calculated as suggested by Vollenweider (1971); and Weber (1973).

$$\text{Ug. Chlorophyll-a/l} = 11.9 \times (OD_{665} - OD_{750}) \times V/l \times \frac{1000}{g} \quad \ldots (10)$$

Where OD_{665} = absorbance (optical density) at 665nm

OD_{750} = absorbance at 750nm

V = Volume of acetone extracted

L = Length of Cuvette (4cm path length)

S = Original Sample Volume (ml)

Ug. = Conversion factor for Chl-a in acetone.

3. Determination of Nitrate-Nitrogen

Nitrogen as nitrates, was estimated using the phenol disulphonic acid method in which 100ml of water is evaporated in a 250ml Erlenmeyer flask. 2ml phenoldisulphonic acid was added followed by 5ml strong ammonia solution. The mixture was stirred and allowed to cool. The absorbance at 410nm was measured using a spectrophotometer. Distilled water was used as a blank.

4. Determination of Phosphate Phosphorous

100ml of water sample was evaporated and 1ml perchloric acid added in a fume cupboard to diggest the salt. The solution was made up to 100ml using distilled water. The absorbance was measured at a wavelength of 882nm using a spectrophotometer.

5. Heavy Metal

To 100ml of water sample collected, 1ml. of Conc. nitric acid was added to acidify and preserve the sample. The acidified sample was subsequently frozen and left in this condition until required for analysis. To analyze sample, 10ml of acid was added to 40ml of water sample and the mixture was heated in a water bath for 30mins. at 90°C. The mixture was then cooled and filtered. The concentration of the various heavy metals was analysed using an atomic absorption spectrophotometer.

6. Microbiology

Total micro-organisms of bacteria and fungi as well as the oil degrading forms in the water samples were enumerated as in the soil samples using 1ml of water and the same medium used for total microbial estimates in soil. For the oil degrading bacteria and fungi, crude oil was added to the medium. The crude oil was separately sterilised by millipose filteration and mixed with equal volumes of carbon tetrachloride before being used to coat the dry surface of agar contained in petri-dishes.

7. Aquatic Macrophytes

The composition, abundance and distribution of aquatic macrophytes at each sampling point was recorded. The biomass of each species was also determined. As in the previous plant samples, all aquatic macrophyte samples which could not be identified in the field were taken to the laboratory for subsequent examination. Aquatic macroinvertebrates associated with the macrophytes were similarly investigated.

8. Plankton Characteristics - Phytoplanton and Zooplankton

Plankton samples were obtained by sinking the net beneath the surface of the reservoir and filtering while towing using a number 21 bolting silk plankton net (70 meshes per linear cm diameter). Samples were immediately preserved in 4% formalin for zooplankton mainly and a drop of conc. iodine solution for phytoplankton.

However, some unpreserved samples were examined fresh on return to the laboratory. Numerical estimations were made by the drop method which is 5 drops of 0.5ml of well shaken sub-sample were examined under a light microscope at 100 x magnification.

The volume of water sampled by the tow-net was determined by the equation:

$$V = \Pi r^2 d$$

Where V = Volume of water filtered (11)

r = the radius of the net mouth

d = the distance the net travelled.

All samples were concentrated to a volume of 35ml prior to their analysis. Subsequently, 05ml. sub-sample was then withdrawn from each well shaken concentrate and plankton samples were preserved in 4% formalin or Lugol's iodine.

(a) Examination of Plankton

Plankton samples were examined either fresh or preserved. Fresh unpreserved samples were examined immediately on return to the laboratory. Preserved samples were examined usually within 10 days after the date of collection under a light microscope.

Concentration of Samples

All samples were concentrated by manual centrifugation or often by leaving them to stand in a sedimentation column for 12 hrs.

Qualitative Examination (Identification of Plankton)

Identification of plankton were made after Penak (1953); Ward and Whipple (1959); Bellinger (1974); and APHA (1980). Phytoplankton were identified to species for the important members usually in terms of relative abundance. The phytoplankton were broadly grouped as Bacillariophyceae, Chlorophyceae, Cyanophyceae and Dinophyceae. The broad groups were subsequently classed into taxa and species.

Quantitative Examination

Numerical estimation of phytoplankton were made by the drop method in which 5 drops of 0.5ml of well shaken sub-samples were examined under a light microscope.

Abundance

The abundance of the various important taxa in each mole was determined using the formular.

$$D = \frac{N}{V} \qquad (12)$$

Where D = the abundance of species x (number of individuals dm^3)

N = the estimated number of species x per sample

V = the volume of water originally sampled.

Species Diversity Indices

This was used to characterise the plankton community structure and lake trophic status.

The following formula derived from the information theory of Lipsey and Malcom (1981) was used to calculate species diversity.

$$II = \frac{N \log N - S \; ni \log n_1}{ns1} \qquad (13)$$

Where II = Species diversity
N = the total number of individual
S = the total number of species
ni = the number of individuals in taxon x.

Species Diversity

The theoretical maximum diversity (II max) of the plankton community was determined using the equation:

$$II\ max = \log S \qquad (14)$$

Where II max = the theoretical maximum diversity of plankton
S = total number of species.

(b) Concentration of Sample - Zooplankton

Samples were concentrated by manual centrifugation or by leaving them to stand in a sedimentation column. Unlike the phytoplankton, the sedimentation column was usually illuminated from the bottom and side to cause the organisms to move towards the surface from where they were immediately siphoned out. Organisms so collected were either examined live or preserved in final concentration of 4% formalin or lugol's iodine.

9. Fish Biology and Fisheries Analysis

Fish Biology

Fish samples were collected from the various sampling points from gill nets, fish traps and hook and line catches baited with earthworms. Additional specimens were also collected from traditional fishermen within sampling locations. Some of the specimens were identified live while others were transported to the laboratory for identification.

Fish samples were analysed for total length, using a standard one metre measuring board and then dissected. The gonads were examined to determine the sex and stage of gonads development. A5-stage gonad maturity Key based on actual observations of gonads of the fish samples were used to describe the stages as:

(i) Immature - representing young virgin fishes never previously engaged in breeding. Gonads were very small and transparent; not easily differentiated into males and females as eggs were not yet visible to the naked eye.

(ii) Mature - Gonads developing or opaque and developed; in females ocytes clearly visible to the naked eye; in males, milt may be exuded when cut.

(iii) Gravid - Females with swollen ovaries, but eggs not yet ripe; eggs generally yolky with smaller eggs, testes swollen full of milt when pressed.

(iv) Ripe - Females with very large swollen ovaries, large, spherical, golden yellow yelky eggs testa full of milt, exuded under light pressure. The eggs may be easily separated and milt may flow from the vent freely with the least pressure on the abdomen.

(v) Spent - Ovaries and testes nearly empty. Recently spent ovaries are flabby with few residual eggs. The testes are depleted of milt and in both sexes the gonads are reduced in comparison with stages iii and iv.

Length - Weight Relationship

The length-weight relationship of the fish samples was determined using a modified method of Pennak (1953) of

$$\text{Log } W = \text{Log } a + b \text{ Log } L \qquad (15)$$

Where W = Weight of the fish in gm

L = Standard lenght of the fish in cm

a = Constant

b = an exponent

Condition Factor

The condition factor ('K' value) was determined using the relationship

$$K = \frac{W \times 100}{L^3} \qquad (16)$$

Where K = Condition factor

W = Weight of the fish in gm

L = Standard length of the fish in cm

Weight of Fish

The weight of fish samples was taken with a top loading slater balance to the nearest gramme.

Parasites

The fins, gills and skin of the fish samples were examined with a hand lens for the presence of parasites.

Total Tissue Hydrocarbon

This was determined using the wet digestion method.

Fishery Techniques

The fishery techniques were determined by assessing the catch per unit effort over a one hour period using a baited hook. The fishing gears were also investigated.

Heavy Metals - Bioassays

The fish samples were classified into genus and species and then measured and weighed. For determing toxic heavy metals in fish, it is not suitable to use whole fish, but selected orgams which effectively accumulate these elements. As these elements differ for different metals and species, we sampled four organs from selected fish species. The organs were the gill, kidney, liver and muscle which were obtained by dissecting the identified fish samples. The analysis for heavy metal level was done according to FAO/SIDA (1983) with atomic absorption spectrophotometer. This method involved wet ashing with a mixture of nitric acid and hydrogen peroxide.

The concentration was expressed in Ug g^{-1} wet weight. The concentration factors were calculated to determine the sorption capacity of the examined animals after FAO/SIDA methods.

$$CF = \frac{McA}{McW} \quad (17)$$

Where CF = Concentration factors of heavy metal

McA = Metal concentration in the body of fish

McW = Metal concentration in water.

10. Sediment

A. Collection of Samples

Bottom sediments were collected as appropriate using Erkman Sediment Grab Samples or grab samples were collected and analysed in triplicates. The sediments were washed with sieves to remove debris. The resulting sediment was then preserved in final concentration of 4% formalin. Another set of the washed sediment sample was immediately stained with rose bengale. The later process conspicuously stained all the macro-benthic invertebrates red except members of the mollusca. The organisms were then identified and classified after the method of Edmonson (1959). Samples for physico-chemical and other biological analysis were immediately after collection allowed to drain followed by the removal of debris manually. They were then immediately preserved in ice to prevent further microbial degration of hydrocarbon.

B. Analysis of Sediment Samples

Analysis of the sediment samples for physico-chemistry, microbiology and macrophyte was identical to those for the soil samples.

3.2.3 Hydrogeological and Geophysical Studies

The geophysical investigation was carried out using an ABEM Terrameter SAS 300 for the groundwater. Three geo-electric depth soundings of array lengths of 1000m each were made in the area. The popular Schlumberger electrode configuration was used and the instrument (ABEM SAS 300) which has a high resolution gave a direct readout of the apparent resistance of the layers in ohms or milliohms. These readings were then converted to apparent resistivities by using the formular:

$$Pa = \frac{(L^2 - I^2)R}{2} \qquad (18)$$

Where Pa = apparent resistivity (m)

L = half the current electrode separation (m)

I = half the potential electrode separation (m)

R = resistance of the layer (ohm)

Five curves made of the apparent resistivity (pa) against the electrode separation (8AB/2) for each of the geoelectric soundings were interpreted by automatic computer evaluation using Dar.Zarouk curves. The geoelectric sections that show the resistivities and the depths to the corresponding layers were then estimated.

1. Physico-chemical Characteristics of Groundwater

The water and soil samples for hydro-geochemical and hydrogeological analysis were collected from recently drilled S.P.D.C. boreholes purposely selected from 3 out of the oil-field locations in the area, specifically at Elelanwa, Alakiri and Ebubu.

Drilling was achieved by the hydraulic rotary method. During drilling soil samples were collected at 20ft intervals until the real aquifers were reached. Drillings were followed by the installation of castings, well screens, the granting and borehole development. The boreholes were then flushed to ensure satisfactory development of boreholes. Water samples were then collected for hydrogeophysical and dydrogeochemical analysis.

The analysis of borehole water was as in the case for the water samples already described.

For the analysis of soil samples for geophysical and geochemical characteristics it was as in the case of the soil samples previously described.

The particles fractionation of borehole soil samples was carried out using the standard "bouyoucos hydrometer" technique. Prior to transfering the sample to the hydrometer, 50g of the sample was weighed and transferred to a baffled cup to which 10ml of calgon (Sodium hexametaphosphate) had been added.

'Calgon' acts as a dispersing agent: (To obtain calgon 5% W/v, 50g of 'calgon' is dissolved in water followed by the addition of sodium bicarbonate to bring the final pH of the sample to pH9; The mixture was then diluted to 1 litre).

To obtain the amount of sand in sample, the hydrometer was removed and the suspension shaken vigorously. The sample was then left undisturbed for 30 seconds.

After the interval, the hydrometer was replaced carefully and its reading taken after 30 seconds. The hydrometer was then removed and the temperature of the suspension recorded. To compensate for temperature variations, for each degree rise in temperature above $20^{o}C$, 0.3 units was added while for each degree fall 0.3 units was subtracted. The amount of particles which settled at the end of the 40 seconds gave the percentage of clay and silt. The difference in weight between the total weight of the sample and the corrected hydrometer reading gave the weight of sand. The percentage composition of the sand was obtained by dividing the weight of the sand by the total weight of the soil and multiplying by 100.

To obtain the amount of clay present, the suspension was vigorously shaken and the sample left to stand for 2 hrs. The hydrometer reading was also taken as in the case of sand. The corrected hydrometer reading gave the amount of clay sample present. The percent clay was also obtained as in the case of sand. The principle is that at the end of 2 hours, the sand and silt must have settled out of suspension. The difference in weight gave the percentage silt. The weight of silt was obtained by subtrating the combined weight of clay and sand from 100.

2. Microbial Flora

Analysis of ground water for microbiological features was carried out as decribed for surface previously.

3.3 SOCIO-ECONOMIC STUDIES

The sampling procedure involved first contact and negotiations with the relevant community/village heads. The households and villages sampled were selected on the basis of the multi-stage cluster sampling technique. 12 out of the 24 villages that make up the 6 communities in the study area were subsequently chosen as the first-stage sampling unit or the primary sampling unit (pSU). The selected households from the sampled villages formed the second stage units. Thirty households were sampled from each village that formed part of the first stage or primary sampling unit or cluster. A total of three hundred and sixty households were used for the study.

Data were collected by observations and the use of structured questionnaires as well as interview schedules. The structure of the questionnaires were based on the specific objectives of the study. The questionnaires were administered to the selected households. Questionnaire administration was done with the help of assistants who were indigens of the 6 communities that make up the study area. The assistants assisted with the interpretation of the language.

The type of data collected by the use of the questionnaire or by visual observation include the socio-cultural background of the people viz; sex, status, religion, primary and secondary occupation, farming activities, with respect to crop and livestock production, land ownership, crop and livestock production systems, household size, and education. Others include fishing, practices petroleum related trades, consequences or impact of oil production or activities in the area among others.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 SOIL AND VEGETATION STUDIES

The results of the soil analysis (in Appendix A) indicate that with the exception of the Port Harcourt North (PHNT) and Port Harcourt South (PHST) transects oil pollution did not affect the other soils. Appendix A (10) shows that even within the PHNT oil pollution could not be detected beyond the 150m from the spill point while along the PHST (Appendix A(5) it could be detected up to 250m from the spill point also. The detection of hydrocarbon does not always indicate oil pollution as they may be of biogenic origin such as in the waxy coating of leaves. However, because of the values obtained here 8 - 860ppm which are far in excess of levels of biogenic origin (5 - 50ppm) the source of the hydrocarbon must have been crude oil.

The values of the pH, EC, organic carbon, PO_4, N, NO_3^-, Na^+, K^+, Ca^{2+} and Mg^{2+} among others investigated show that the soil was still very suitable for agricultural purpose. Evidences from the abundant and healthy crop and forest vegetation in the area support these conclusions.

Soil Microbiology

The distribution of bacteria and fungal organisms in the Soil are shown in APPENDIX B. Except for the PHNT and PHST, transects, the bacteria populations were within normal levels. Among the fungal organisms, the most dominant species were those of Aspergillus, Fusarium, Pythiaceae and Thizoctoria. Pythiaceae were encountered in every moist conditions especially during the rainy season sampling. Penicillium and Aspergillus were isolated in the dry season mainly Trichoderma and Fusarium and they did not exhibit any clear moisture preferences. Organic materials which are incorporated during microbial growth showed varied carbon: Nitrogen ratio. Since the values are all below 20, favourable conditions that satisfy the nitrogen need of the micro-organisms which decompose organic residues exist. It has been demonstrated that ratios above 20 usually result in immobilisation of nitrogen in the soil and thus nitrogen fertilizers become imperative.

The features of the soil pit profiles are presented in Table 4. From it we observe that in the PHNT and PHST transects little leaf litter occur. This is because much of the transects fall along the right of way. The majority of the transects show only three horizons within the 0-120cm depth. Zone A ranged from 0-5cm for the very thin zones, 0-18cm for the majority of zones and 0-29cm for some of the very thick layers. Similarly, zones B ranged from 5-36 cm and 13-39cm. Some zones showed a thickness of 28-105cm. Various shades of colours which included light brown, dark brown, orange yellow, dark grey and reddish among others were observed. The dark greyish-brown colours result from high humus content.

The soil surface contain some leaf litter consisting of fresh and partly decomposed leaves and other plant materials. The loamy and granular nature of the top horizon are the result of microbial action on the humus.

The subsoil contained only very little humus. The reddish-brown colour observed in this zone results from the presence of ferric oxide. This is an indication of good drainage and aeration property. The brown, and yellow soil colours are indicative of the presence of iron in a hydrated form such as limonite. Grey soil colours are indicative of the presence of iron in the reduced state. The reddish-brown soils have numerous pores between structural aggregates and these enhance air and water circulation in the soil. Grey colours in addition are indicative of iron in oxygen defficient soils.

Table 4: Summary of Transect Soil Pit Profile Features of Port Harcourt and Environs

Transect	Horizon	Type Description
PHNT	A_1	0 - 13cm Very dark (almost black) sandy layer that is very oily and a bit greesy. Has few dead roots. Has little humus, no leaf litter and boundary with
	A_2	13 - 18cm Light brown, sandy and oily; has dark oily patches soft and dense; merging into
	B	18 - 48cm Yellowish brown, fairly silty layer with few gravels; merging into
	C	48 - 120cm Very oily clay speckled with reddish yellow patches. Very greasy and dense. Deep down the pit, water with a film of oil sips into the pit.
PHNET	A	0 - 13cm Dark brown loam with fine sand, porous, with little humus, dead and fibrous roots, clearly separated from
	B	13 - 39cm Yellowish brown sandy silt, with tap roots and humus, merging into
	C	39 - 120cm Reddish brown clay with occassional tap roots and pieces of rock.

Table 4: Contd.

Transect	Horizon	Type Description
PHNWT	A	0 - 15 Dark brown loamy soil with a lot of leaf litter and humus, many dead and fibrous/branched root, porous, merging into
	B	15 - 42cm Brown sandy loam, porous, with some humus, tap roots, insect burows with an irregular boundry to
	C	42 - 120cm Orange red clay with fine sand, tap roots and dark spots.
PHST	A	0 - 8cm Very dark brown loam, very porous, little humus, some root systems; merging into
	B	8 - 30cm Light brown Sandy Silt, fairly porous, contains some tap roots and decayed roots, few gravel; merging into
	C	30 - 120cm Dark brown clay, occassional tap roots and pieces of rock.
PHSET	A_1	0 - 11cm Dark brown loam, with many fibrous and tap roots, contains some humus and leaf litter, porous; merging into
	A_2	11 - 38cm Light brown sandy silt, few tap roots, a bit porous; clear, irregular boundary with
	B	38 - 64cm Dark brown silt with fine sand, has red streaks occassional tap roots; fairly porous; merging into

Table 4; Contd.

Transect	Horizon	Type Description
PHSET	C	64 - 120cm Orange red silty layer with no roots; contains few rock fragments.
PHSWT	A	0 - 5 cm Dark brown loamy soil, contains plenty humus and leaf litter, many fibrous and branched roots, porous, a bit coarse, irregular boundary with
	B	5 - 36 cm Reddish brown loan, contains some humus, some fibrous and tap roots, porous; irregular boundary with
	C	36 - 120 cm Orange red silty clay, occassional tap roots, greesy and oily, not quite porous, some water with oil filme was sipping into the pit, some big tap roots and black streaks.

Plant Tissue Analysis

Five of the plant species encountered in the area were analysed for foliar chemical composition. Table 5 shows that of the five species sampled, the range of the primary and macro-nutrients indicate the plants were healthy, and not lacking in most nutrients. However, the concentration of nitrogen, phosphorous and sulphates were low.

Entomology

In terms of entomological relationship, six orders of insects belonging to the orthopthera (grasshoppers, mantids and crickets); Lepidopthera (butter flies and moths); Hymenoptera (Ants, bees, sand flies and wasps); Hemiptera (tree bugs); colesptera (beetles and weavils); Odenato (dragon flies and damsel flies) and the diptera (true flies) were encountered. Table 6 shows the distribtution of these insects. From the Table we observe that the orthopthera are represented by four species; Lepidoptera, seven species; Hymenoptera, one species; Hemiptera, two species; coleoptera, one species and the Odonata two species. In terms of abundance, the three most abundant orders are the Lepidoptera, orthoptera and Coleoptera. In terms of Species abundance, the three most abundant species were Neptic Sp., Myliabris Sp. and Holoperna gerstaeckeri.

Table 5: Folia Chemical Composition of Some Species Within Port Harcourt and Environs Field/Transects

		%						(ppm)			
		K	Ca	Mg	Na	N	P	Fe	Mn	SO_4	CC_2
Newbouldia	laevis	0.04	1.50	0.16	0.06	2.10	0.07	96	340	350	2.20
Baphia	nitida	1.60	0.67	0.20	0.08	3.56	0.40	144	150	230	2.35
Pentaclethra	macrophylla	1.40	1.30	1.14	0.05	2.20	0.20	210	96	116	2.55
Landolphis	Owerriensis	1.34	1.20	0.30	0.04	1.66	0.15	150	450	303	2.41
Gnestis	ferruginea	1.80	1.60	0.32	0.06	1.90	0.12	160	282	485	2.58

Table 6: Checklist of Insect Fauna Within the Field/Transects of P.H. and Environs

ORDER	FAMILY	GENUS	SPECIE	ABUNDANCE
Orthopthera	Pyrgomorphidae	Zonocerus	Variegatus	80
"	Acrididae	Eyprepoenesis	plorans	133
"	"	Cantantops	melanostictus	38
"	"	Holoperona	gerstaeckeri	144
Lepidoptera	Satyridae	Bicylus	dorothea	26
"	"	Bicylus	Sp.	01
"	Aracidae	Bematistes	Sp.	36
Lepidoptera	Acraeidae	Acraea	bonasia	42
"	Nymphalidae	Bebeatia	Sp.	46
"	"	Neptis	Sp.	204
Lepidopthera	Nymphalidae	Catùna	Crithea	42
Hymenoptera	Formicidae	Black ant		140
Hemiptera	Pentatomidae			18
"	Reduriidae	Petalocheiras	Sp.	82
Coleoptera	Meloidae	Mylabris	Sp.	160
Odonata	Libellulidae	Palpopleura	lucia	40
Odonata	Libelludidae	Palpopleura	portia	56

Crop Pathology

The tree species and crops showed some signs of disease. However, most of these infection were usual plant diseases not associated with pollution, as observed elsewhere outside the oil fields. It is also noteworthy that no disease epidemic occured in the vegetation. Most of the diseases were caused by viral and fungi pathogens. The commonest diseases were those of the viral mosaic disease and leaf spot disease which are normal with vegetation in other similar agricultural areas.

4.3 AQUATIC AND SEDIMENT STUDIES

The results presented in Table 7 indicate that the physico-chemical characteristics of the selected streams in the area show little dynamic features. The water temperature has been demonstrated to fluctuate between 26.3 - 27.1^{o}C. Lowest water temperature and highest water temperature occured in streams C and A respectively. These values show inverse relationship to the depth of the stream and the density of the surrounding vegetation also. It is therefore reasonable to suggest that the water mass primarily dictate the water temperature. Other factors which also affect the water temperature are dissolved substances, wind and vegetational cover. The smaller water mass at stream A thus required a smaller heat energy to raise the water temperature in comparison to streams B and C with greater mass. It has been shown by Kibby (1971) that low water temperature and turbidity which result in low photo-synthetic capacity of phytoplankton and light penetration cause a decline in primary productivity values.

It may be an indispensable factor in explaining the distribution pattern as well as the primary productivity feature of the streams.

The water PH show minimal fluctuation of insignificant range (8.00,- 8.30). Analysis of data on PH recorded during the study shows that the PH of the streams is largely circumneutral. The PH range recorded also indicate that the streams are largely circumneutral. The PH range recorded also indicate that the stream water is soft water. The water hardness as indicated by the PH and circumneutral property are characteristics conducive for high biological productivity. The existence of this pattern is due mainly to phytoplankton photo-synthesis which results in carbon dioxide removal. We also observed compared to the streams, that a lower PH occured in stream C. This arises from decreased algal growth and photosynthetic rate which show positive correlation. Since higher levels of productivity results in higher PH values higher carbondioxide utilization and lower free carbondioxide, the PH may be an alternative index in productivity estimations.

Table: 7: Physico-Chemical Characteristics of Sampled Streams in Port Harcourt and Environs

Physico-Chemical Characteristic	Stream A	B	C
Sampling Time	AM	AM	AM
Colour	Colourless	Colourless	Colourless
Turbidity	1.0	1.0	1.0
Flow rate	2m Sec	4mSec	2.5mSec.
Alkalinity	35.1	37.2	37.6
Temperature	27.0	27.1	26.3
Depth	5.0cm	18.0cm	25.0cm
Total Solids	226.0	253.0	306.0
Suspended Solids	3.0	3.6	5.1
Conductivity	35.3	36.1	36.4
PH	8.3	8.1	8.0
Dissolved Oxygen	$5.3dm^3$	$6.2dm^3$	$7.3dm^3$
BOD	1.40	1.30	1.10
THC	38	36	43
Na	1.1	1.7	1.6
K	3.0	3.0	3.5
Ca	ND	0.18	0.23
Mg	0.01	0.03	0.03
Mn	ND	ND	ND
Fe	1.33	1.14	1.43
PO_4-P	1.25	1.23	1.20
NO_3	26.5	25.8	26.1
NH_4	ND	ND.	ND
NO_2	0.08	0.06	0.07
SO_4	110	110	130
Free CO_2	2.00	2.20	2.30
1^o Productivity	4.70	5.20	6.50

The results obtained in this study show that the PH generally rises with decreasing alkalinity (bicarbonate), and the higher alkalinity co-occur with higher free carbon dioxide concentrations. Based on kinetic considerations, the latter implies that the carbon dioxide and bicarbonate alkalinity are not in equilibrium. Thus changes in carbon dioxide concentration do not cause commensurate changes in bicarbonate concentrations. The occurrence of higher alkalinity at lower free carbon dioxide values appears to be due to the nature of the bed-rock and the geochemistry of the sediments. If as has been demonstrated here that levels of alkalinity show positive correlation with productivity, it indicates that the streams are satropic.

The conductivity values obtained in this study show that lower values occur in stream A, intermediate values in stream B and maximum value in Stream C. The higher conductivity obtained in stream C is due to the inflow of smaller tributaries, some of them seasonal tributary streams, run-off from the catchment area and higher erosion of soils leading to increase in major irons in the stream. The generally high water temperature may also permit the dissolution of the surrounding rocks. The stream waters exhibit bicarbonate alkalinity mainly, and in consequence, the conductivity of the stream is related to the concentration of major ions.

The free carbon dioxide distribution obtained in this study show that higher values occur in stream C when compared to the other stream values. This may be due to an increase in the rate of decomposition of organic matter with an evolution of larger amounts of carbon dioxide. This process also coincide with the level of suspended solids and dissolved solids. In consequence dissociation of bicarbonates will lead to an increase in free carbon dioxide concentration of the stream water. The lower concentration of free carbon dioxide in steam A arises from a decrease in amount of organic matter being decomposed and higher rate of temperature mediated phytosynthetic rate.

Accordingly, we propose that low concentrations of free carbon dioxide will support rates that utilize considerably higher concentrations of bicarbonates.

In comparatively low concentrations, rates of primary production may be increased much more by an increase in free CO_2 than by an equivalent increase in bicarbonates. The profile of free CO_2 show that generally, higher concentrations arises as a result of the higher rate of respiration by greater nekton and benthos biomass, microbial activity in the sediments, as well as the breakdown of organic matter by micro-orgnisms. The alkaline nature of the water as well as the geochemistry of the drainage basins also contribute to the higher levels of carbon dioxide.

The distribution of dissolved oxygen in this study has been shown to vary with the stream. The major peak in dissolved oxygen observed in stream C arise from the following factors, the higher rate of photosynthetic activity due to higher phytoplankton biomass; and appreciable sedimentation of organic matter brought into the stream during the rains; the higher solubility of oxygen due to lower water temperature prevailing at this stream and an interaction of these factors. The minor values observed in stream A results from the lower rate of oxidative breakdown of organic matter of allochthonous origin, lower oxygen solubility resulting from higher water temperature and weaker wind action. The range of dissolved oxygen in the streams (5.30 - 7.30dm^3) reflects its ability to sustain a higher biomass of aquatic life than is available at present. The range is also high enough to maintain high levels of fish activity and production. The wide fluctuation in the dissolved oxygen values is associated mainly with the irregularity in the intensity and occurence of light. It has been shown by Weber (1973), that the turbidity of a water body was due to high phytoplankton biomass, effluent materials and induced turbulence keeping material in suspension. This leads to wide changes in the amount of organic matter in the water. This possibility is further validated by the moderately fluctuating dissolved oxygen values when practically rain-fall occured.

Microbiology

The microbiological features of Port Harcourt and Environs sampled boreholes, streams and sediment in Table 8 show that highest bacterial count was obtained in the borehole water samples. However, the percentage of hydrocarbon utilising bacteria was very low (0.002 - 0.004%) indicating the possibility of pollution of the groundwater by oil. Intermediate values (0.007 - 0.012%) were obtained in the stream samples while maximum values (0.010 - 0.026%) were obtained in the sediment samples. The higher values obtained in the sediment samples is not surprising since sediments are known to serve as reservoirs for effluent materials and microbial organisms.

For the borehole samples, the potential of their pollution by oil depends largely on the geology of the soil, the soil condition, the composition of the oil and the intensity and duration of the oil spilled. For oil, its viscosity also plays an important role in determining the level of pollution. Although oil may be immodilised in the unsaturated zone in groundwaters with a high water table, it may still be polluted following rain-fall. Here, recharge by fluctuating water table and percolating rain illicit the pollution by the dissolution of the water soluble fraction (WSF) of the crude oil which subsequently reaches the underground water.

It has been known that oil in water and sediment can be removed through microbial action, evaporation, photo-oxidation and dissolution of the water soluble fractions by mainly phytoplankton, algae, fungi and bacteria. (Lipsey and Malcom, 1981).

These organisms have been identified in the area of study notably the hydrocarbon utilizing forms. Often, the abundance of the oil utilising micro-organisms is expected to increase following oil spill in favourable conditions.

Table 8: Microbial Characteristics of Sampled Stream, Ground Water, And Sediment in Port Harcourt and Environs

Sample	Type	Total Bacterial Counts/ ml or g	Total Hydrocarbon Utilisers/ g or ml	Percentage Hydrocarbon Utilisers	Hydrocarbon Utilising Species
Borehole	A	2070	1.3	0.003	Acinetobacter
Borehole	B	2020	1.3	0.002	Acinetobacter
Borehole	C	2140	2.2	0.004	Acinetobacter
Stream	A	240	1.8	0.009	Bacillus
Stream	B	260	2.1	0.007	Bacillus
Stream	C	460	3.2	0.012	Bacillus
Sediment	A	420	2.2	0.010	Acinetobacter
Sediment	B	400	2.3	0.010	Acinetobacter
Sediment	C	720	4.5	0.026	Achromobacter

Phytoplankton

Among the phytoplankton, (Appendix D) Six Species of bacillariophyceae, four of cyanobacteria, eight of the chlorophyceae, and four of the dinophyceae were observed. In terms of dominance status and with regards to species diversity, the order is chlorophyceae baccillariophyceae dinophyceae. However, in terms of Species abundance, the order of dominance is cosmarium bioculatum, Ankistrodesmus Spiralis, A. falcatus, Melosira granulata, Chrococcus limnetica, Microcystis aeruginosa and Ceratium Cornutum. With regard to the streams, the order of phytoplankton dominance was stream C Stream B Stream A. The appreciable species diversity of the phytoplankton would enhance high primary productivity. The composition of the chlorophycean algae is not indicative of potential pollution but rather a reflection of the concentration of their nutrients.

Macrophytes

For the aquatic macrophytes, only five species were recorded (Table 9). These were species of floating algae namely Salvinia nymphellula, Postia Stratoites, and Ceratopteris Cornuta. The attached algae were Utricularia inflexa, and ceratophyllum demersum. In general their abundance was very low. Many of the aquatic insecta recorded were recovered from the surrounding aquatic macrophyte.

Table 9: Aquatic Macrophyte Flora of Stream in Port Harcourt And Environs Sampled Streams

Nature of Vegetation	Specie	
FLOATING	Salvinia	nymphellula
	Pistia	stratoites
	Ceratopteris	cornuta
ATTACHED	Utriculoria	inflexa
	Ceratophyllum	demersum

Macroinvertebrate

The distribution of macro-invertebrates shows that except for oligochaeta, no other benthic macro-invertebrates were encountered within the streams only aquatic insects and one freshwater crustacean was recorded.

Table 10: Checklist of Macroinvertebrate Stream Fauna in the Area

CLASS	SPECIE	COMMON NAME
INSECTA		
	Cylindrostethus Sp.	Pond Skater
	Ptilomera Sp.	Pond Skater
Hemiptera	Notonecta	Water Boatman
Hemiptera	Ranatra	Water Stick Insect
Odonata	Pantala	Dragon fly
Hemiptera	Laccotrephes	Water Scorpion
Odonata	Ischnura	Damsel fly
Ephemeroptera	Cloron	Mayfly
Hemiptera	Amorgius	Water Bug.
Diptera	Chironomus	Blood Worm
CRUSTACEA		
	Potamonautes	Freshwater Crab
OLIGOCHAETA		
	Tubifex	
	Nais obtusa	
	Enchytraeus	net worm
	Limnodrilus	Yoruba worm

In all, ten species of aquatic insects were found, (Table 10). These were two pond skaters, one water boatman, one water stick insect, one dragon fly, one water scorpion, one damsel fly, one mayfly, one water bug and one blood worm.

The distribution of zooplankton (Appendix E) shows that they belonged to the rotifera, eleven species were recorded. The group was dominated by Brachionus angulams, Asplanchna brightwelli, Brachionus calyciflorus and Brachionus caudatus. The cladocera, was represented by four species which exhibited the following dominance pattern, Macrothrix Spionosa, Alona Sp., Ceriodaphia Cornuta and Diaphanosoma excisum. The Copepoda was represented by two species which showed the order of abundance Mesocyclop Sp., Thermocyclop Crassussi. The higher abundance of zooplankton organisms in stream C is associated with the higher phytoplankton biomass and productivity in this stream.

FISH BIOLOGY

From the result of the ichthyofaunal distribution (Table 11) a total of 16 fish species were encountered during the study. All fish species were present in stream C, 6 species in stream B and 4 species in stream A. The number of species in stream C, may be associated with its location in relation to streams A and B. It is also highly probable that streams A and B drain into stream C. This observation may in part explain the presence of all 16 fish species in stream C. Granted that the sampling intensity and gear were identical at all locations, the order of abundance for Species in the 3 streams is stream C B A.

With the sizes of the fishes encountered, we note that most of the fish were juvenile fish ranging in sizes from 4cm - 20cm. Consequently, none had attained maturity in terms of reproductive status such as gonad maturation. Nevertheless, two species namely Tilapia Zilli and Clarias Lazera with two distint food and feeding habits were examined for heavy metal tissue analysis.

In all the fishes caught, none showed any signs of physical deformities, parasite infestation or abnormal growth. The 16 fish species encountered belonged to 13 families. Apart from the family Cichlidae which were represented by 4 species, all other 12 families were represented by one species each.

Table 11: Checklist of Ichthyofauna (Fishes) within the Sampled Streams in Port Harcourt and Environs

FAMILY	SPECIES		ABUNDANCE STREAM A	B	C
Bagridae	Auchenoglanis	biscutatus	–	–	2
Osteoglossidae	Heterotis	niloticus	–	–	3
Polypteridae	Calamichthys	calabaricus	–	–	7
Symbranchidae	Symbranchus	after	–	–	3
Pantodontidae	Pantodon	bucholizi	–	–	4
Cichlidae	Hemichromis	bimaculatus	2	3	5
Anabantidae	Ctenopoma	Kingsteyae	–	–	1
Characinidae	Hepsetus	Odoe	–	–	4
Osteoglossidae	Heterotis	niloticus	–	–	1
Malapteruridae	Malapterurus	electricus	–	3	8
Ciclidae	Sarotherodon	Galileae	4	6	11
Ciclidae	Sarotherodon	nilotica	3	6	10
Cichlidae	Tilapia	Zilli	4	8	15
Clariidae	Clarias	lazera	–	3	7
Channidae	Ophiocephalus	obscuro	–	–	3
Cyprinidae	Labeo	Senegalensis	–	–	3

Bioassay

The results of the investigations on the distribution of heavy metals in the 3 streams of the area showed that the metals Mercury, Chromium, Cadmium, Nickel, and Venadium were below detectable levels (Table 12). The levels of the following heavy metals; viz. Lead, Cromium, manganese, Mercury, and Copper were reasonably higher in the Sediment Samples (Table 13) than in the water samples (Table 12). These levels did not indicate their source to be due to oil pollution but due to other non-point sources. This is because these concentrations are quite lower than the maximum allowable levels of the metals.

Table 12: Concentrations of Metals (ppm) in Water Samples of the Selected Streams in the Area

Metal	Water Sample Source Stream		
	A	B	C
Sodium	26.70	28.60	40.20
Calcium	5.75	5.70	6.40
Magnesium	8.20	8.10	1.00
Copper	0.07	0.07	0.07
Iron	3.80	3.74	4.10
Zink	0.31	0.31	0.33
Manganese	0.06	0.06	0.05
Venadium	ND	ND	ND
Nickel	ND	ND	ND
Cadmium	ND	ND	ND
Cromium	ND	ND	ND
Lead	ND	ND	ND
Mercury	ND	ND	ND

Table 13: Heavy Metal Concentration of Sediment from the Sampled Streams (ppm)

Heavy Metal	Sediment		
	A	B	C
Lead	0.46	0.44	0.50
Cromium	0.42	0.31	0.38
Copper	0.08	0.14	0.84
Nickel	ND	ND	ND
Venadium	ND	ND	ND
Cadmium	ND	ND	ND
Mercury	0.02	0.02	0.02
Zinc	0.03	0.03	0.04
Iron	0.40	0.34	0.38
Manganese	0.78	0.93	0.73

Table 14: Heavy Metal Concentration (mg/kg^{-1} dry wt.) In Organs of Fish at Stream C

Fish	Specie	Organ	Heavy Metal						
			Pb	Zn	Cu	Cd	Hg	Ni	V
Clarias	Lazera	Liver	2.16	94.00	5.35	0.86	0.10	ND	ND
		Kidney	4.56	113.00	5.16	1.36	0.46	ND	ND
		Gill	10.70	141.00	5.65	0.78	0.23	ND	ND
		Muscle	2.38	53.00	2.13	0.29	0.15	ND	ND
Tilapia	Zilli	Liver	2.14	71.80	5.72	0.47	0.12	ND	ND
		Kidney	3.76	137.00	3.65	0.83	0.87	ND	ND
		Gill	4.41	84.30	2.41	0.52	0.04	ND	ND
		Muscle	2.87	24.8	0.87	0.21	0.19	ND	ND

The concentrations of the different heavy metals in the surface waters might have merely reflected normal accumulation or concentrations from substantial run-off following usual high precipitation in the area rather than direct interaction of the dynamics of geochemical cycles. The evidently higher concentration of these heavy metals in the sediment than in the surface waters may have resulted from their accumulation from various non-point sources. It is thus not a direct indication of the intensity of the oil pollution. Sediments have been shown to readily adsorb metallic ion thus acting as a "reservoir" of heavy metals.

Defining the maximum permissible level or concentration of metals in water is of fundamental importance in studying metal toxicity. Similarly, identification of the causes and mode of action of the toxic metal and their effect on the metabolism, general physiology and survival of aquatic life is necessary. The establishment of empirical relations between an assessment of direct toxicity to organisms and the status of productivity in polluted water based on valid statistical, experimental and ecological considerations is required. To arrive at an estimate of safe conditions at which organisms would survive, allowance would have to be made for sub-lethal ecologically significant adverse effects on aquatic organisms, including reduced growth, fecundity, and other alterations on normal behaviour and physiology.

It has been shown that enzyme activity of organisms can be altered by metals (Libsey and Malcom, 1981). There are however, other sublethal effects on endocrinology, cell biology, hematology, histopathology and various physiological functions such as respiration, circulation, and osmoregulation.

It has been suggested that, for measuring toxic heavy metals in fish, it is not advisable to use the whole animal body, but organs should be selected which especially accumulate these elements. Since they may differ for different species and metals, we sampled four organs of two fish species in the same location of the stream. Table 14, gives the data for Clarias and Tilapia in muscle, liver, kidney and gill. In both fish Cu is concentrated most in the liver while Cd and Hg are more in the kidney; Zn and Pb are concentrated most in the gill of Clarias and in the Kidney of Tilapia. Significant differences were found in the metal concentrations of the same organ of the two species. This was especially stricking for Cu in the liver, for Zn in the gill, for Cd in the liver and Kidney, for Hg in the Kidney and for Pb in the gill.

Studying the weight dependency of the metal concentration we found that, for example, in the liver, the Hg concentration increases in the Tilapia, but decreases in the Clarias. The observed fluctuations show that transient pollution may have occured in the stream as reflected in the metal concentrations of the fish organs. For Cd. this can be connected to the use of fertilizers in the catchment area during the rainy season, while higher amounts of Pb may reach the water due to the traffic in the surrounding roads.

Sediment Analysis

Compared to the stream water, the concentration of the hydrocarbon utilising bacteria (HUB) in the sediment was higher (Table 8). This may be related to the oil spill which occured in the area being washed into the sediments in stream C. However, the bacterial population can be an indicator of the state of an environment in several ways. Firstly, bacteria number or biomass roughly reflects the concentration of organic matter or pollutant in the sediment. Secondly, the presence of particular bacterial groups can be used as indicators of inflow of pollutants, Thirdly, the bacterial flora, or community structure can also indicate at least to some extent, the environmental conditions, including physico-chemical factors, the quality of organic matter and/or biological activities of other organisms surrounding them. Based on the results shown here, there is evidence of an oil spill. However, the oil concentration as evidenced by the percentage of HUB indicate that some of the oil has been lost through microbial action, evaporation, dissolution and photo oxidation. The physico-chemical characteristics of the sediment is shown in Appendix F.

4.3 HYDROGEOLOGICAL AND GEOPHYSICAL STUDIES

Geophysical investigations for depth to groundwater level in the study area were made as part of the assessment studies to investigate the groundwater pollution in the area. To achieve this objective, three geoelectric depth soundings were made in 3 sampled locations in the area (figures 2,3, and 4).

Each of the geoelectric sections shows that the subsurface geology is primarily made up of aquifer and aquitards forming a multi-aquifer system as summarised in Appendix G and Tables 15,16 and 17. For the vertical electric soundings made at BH_1, BH_2, and BH_3, the water table was met at 60.25m, 70.90m and 72.41m respectively. Also the base of the aquifer was not met for the 500AB/2 electrode spread signifying that the aquifer is thick. Table 18 summarises the depth to the water table in each of the sounding stations as obtained by the geophysical method.

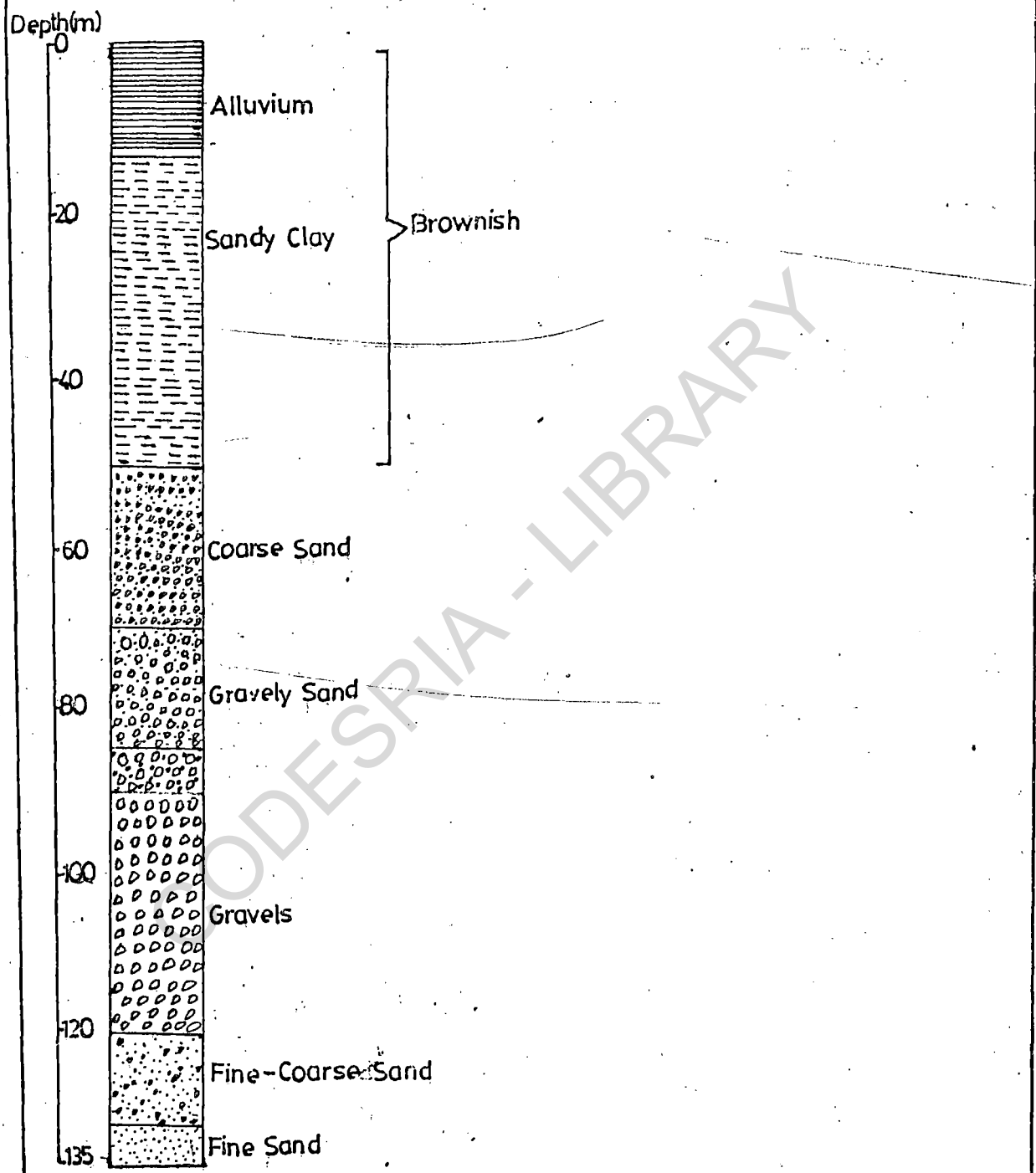

FIG. 2 STRATA LOG OF BOREHOLE NO. 1 IN PORT HARCOURT AND ENVIRONS.
Source: Fieldwork, 1993.

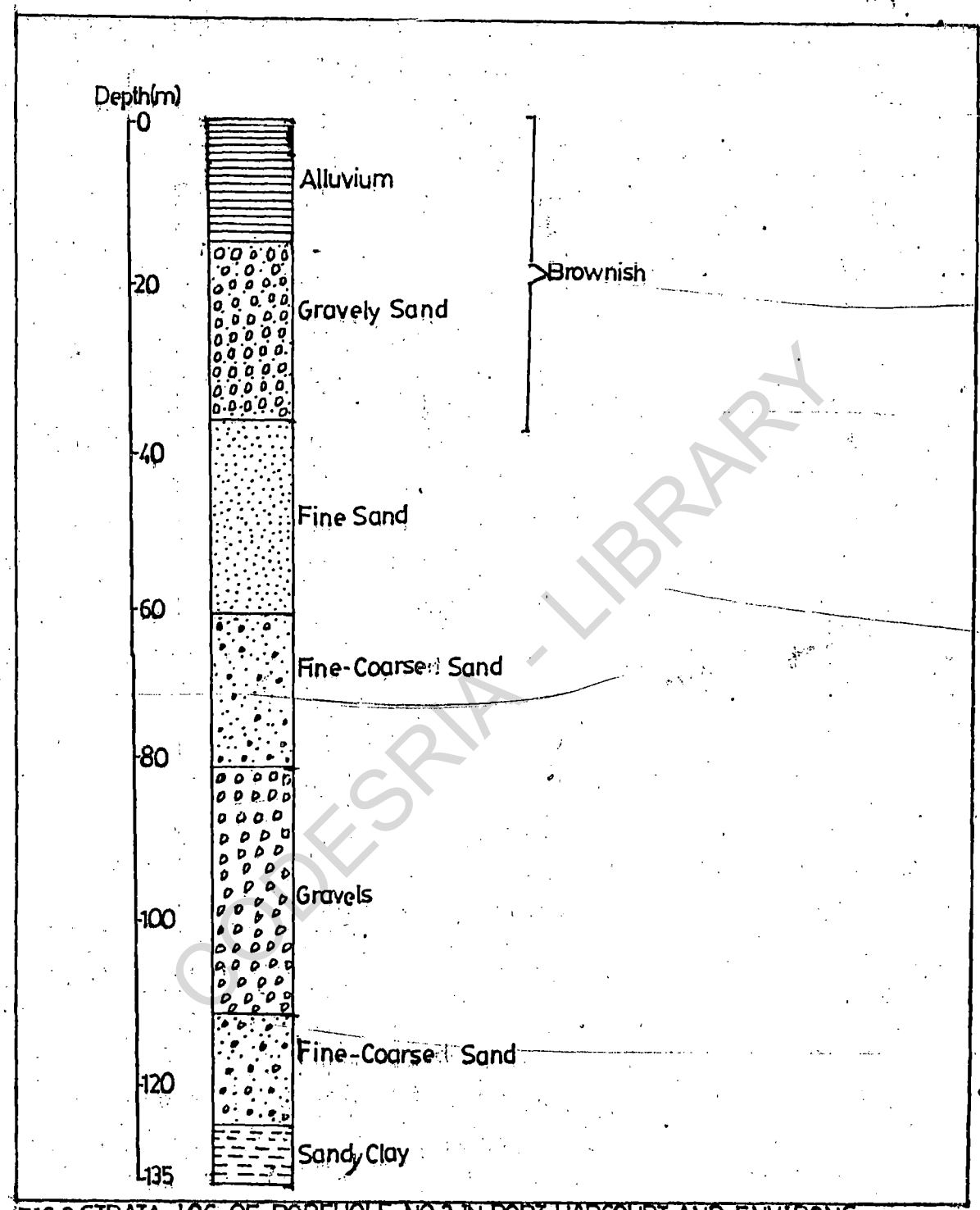

FIG. 3. STRATA LOG OF BOREHOLE NO. 2 IN PORT HARCOURT AND ENVIRONS
Source: Fieldwork, 1993

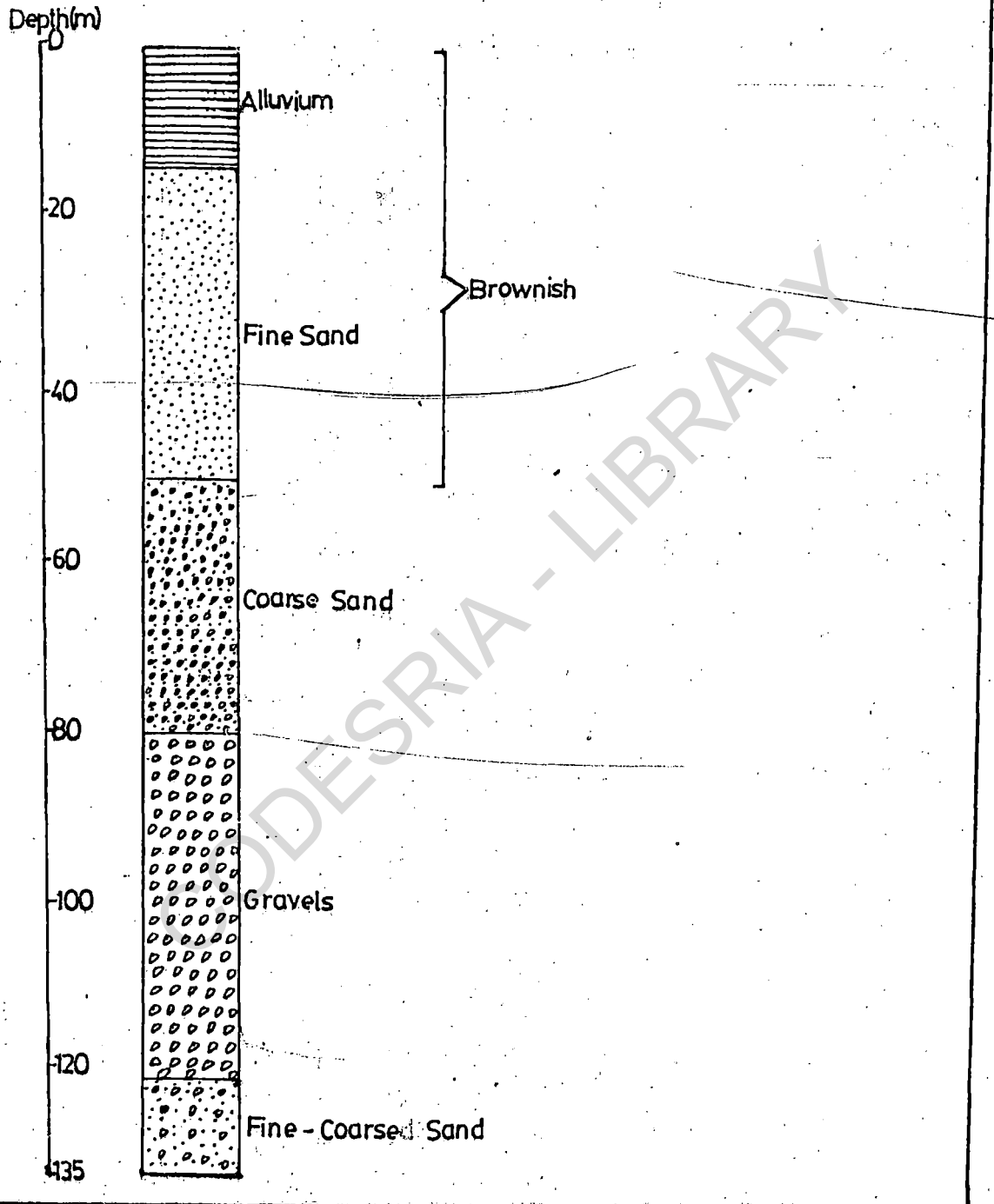

FIG.4 STRATA LOG OF BOREHOLE NO.3 IN PORT HARCOURT AND ENVIRONS
Source: Fieldwork, 1993

Table 15: Summary of Ves Results at P.H. and Environs BH3

Layer No.	Depth to the bottom of the layer from the ground surface (m)	Thickness of the layer (m)	Resistivity of the Layer (nm)	Probable Rock Type
1	4.63	4.63	2336.69	Lateritic top soil
2	12.79	8.16	272.39	Wet Sandy Shale
3	72.41	59.62	3038.21	Sandstone
4	Base not reached	Base not reached	414.28	Saturated Sandstone

Table 16: Summary of Ves Results at P.H. and Environs BH2.

Layer No.	Depth to the bottom of the layer from the ground surface (m)	Thickness of the layer (m)	Resistivity of the layer (nm)	Probable Rock type
1	3.90	3.90	150.16	Lateritic topsoil
2	15.60	11.70	328.10	Wet Sandy Shale
3	70.90	59.20	2609.84	Sandstone
4	Base not reached	Base not reached	458.55	Saturated Sandstone

Table 17: Summary of Ves Results at P.H. and Environs BH1

Layer No.	Depth of the bottom of the Layer from the ground surface (m)	Thickness of the Layer (m)	Resistivity of the layer (nm)	Probable type
1	0.90	0.90	526.22	Lateritic Soil
2	2.90	2.00	36.22	Wet Shale
3	3.89	0.99	405.64	Wet Sandy Shale
4	60.25	56.36	3543.39	Sandstone
5	Base not Reached	Base not Reached	447.48	Saturated Sandstone

Table 18: Summary of the Depth to Water Table at Vesstation

Location	By Geophysical Method (m)	Aquifer Unit
P.H. and Environs BH1	60.25	Sandstone Unit of Benin Formation
P.H. and Environs BH2	70.90	Sandstone Unit of Benin Formanton
P.H. and Environs BH3	72.41	Sandstone Unit of Benin Formation

The graphic representation of the grain size data are represented as (i) histogram (ii) cumulative frequency curve (figures 5 - 14). The histogram indicates that most of these samples have Unimodal grain size distribution with coarse-medium sand grain population dominating. From the cumulative frequency distribution it is observed that most of the samples exhibit more than three straight line segments separated by sharp break between the segments. The slope of the straight line as well as the position of the breaks between segments reflect the mechanism of particle deposition. The fine end Segment of the distribution resulted from deposition of particles carried in suspension, while that at the coarse end occured from particles transported by rolling and sliding. One of the noticeable characteristic of this analysis is that most of the samples show more than the cummulative frequency curve.

The analysis showed no accumulation of silt or clay with the sands. The sorting values depicted that there is fair variation in the saltation population which accounted for more than 95% of the distribution. The steep slope of the line of distribution in the cummulative frequency curve is indicative of good sorting. It is noted that water acting on sediment serve as a mechanism of selection and removal of particles, thus contributing to a process of sorting. The general lack of silt or clay particles and the mean grain size of all the samples are indicative of apparent regional permeability since there is minimum cementation of the beds and hence high porosity of the sand grain.

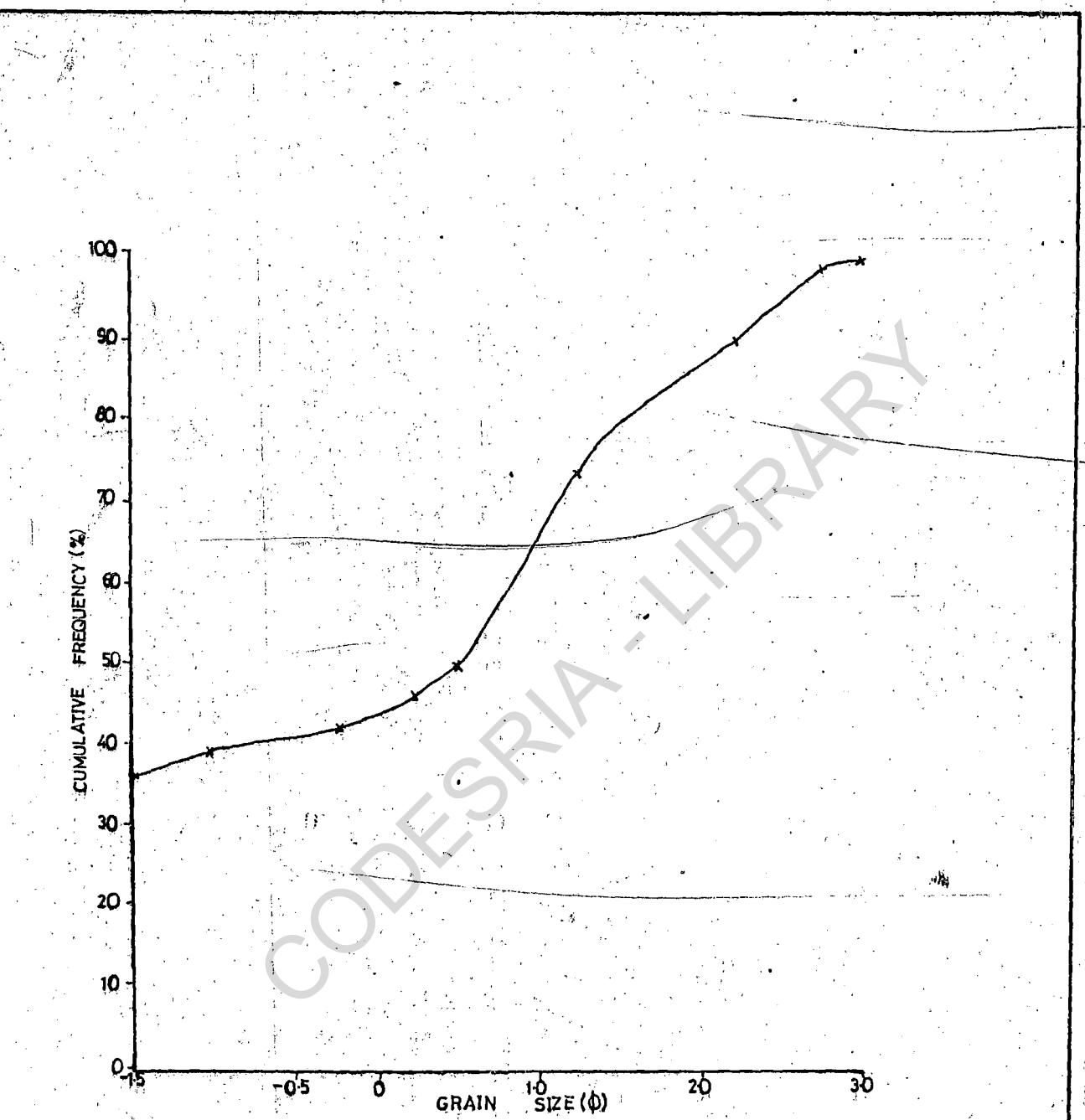

FIG. 5. PARTICLE SIZE FEATURES OF 20m BOREHOLE SOIL SAMPLE OF PORT HARCOURT AND ENVIRONS (Source: Fieldwork, 1993)

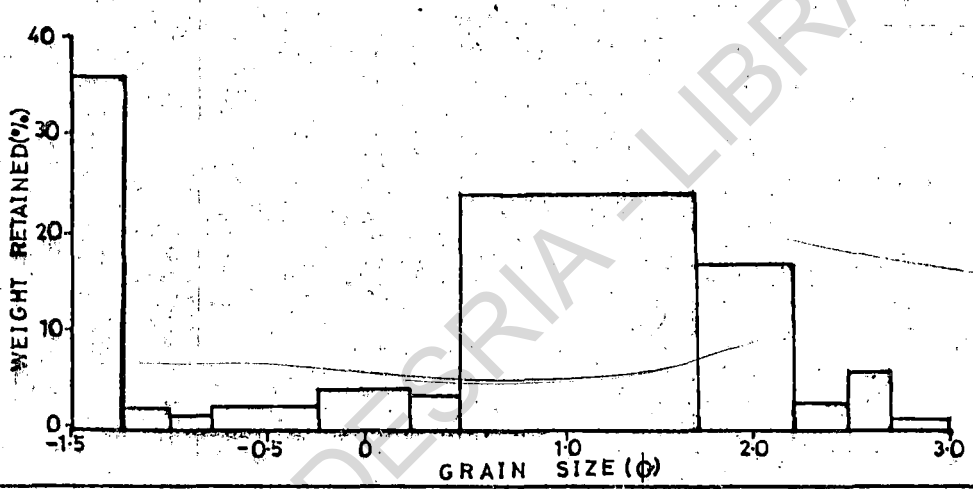

FIG. 6 GRAIN SIZE FEATURES OF BOREHOLE SOIL SAMPLE OF PORT HARCOURT AND ENVIRONS AT 20m. DEPTH. (Source: Fieldwork, 1993).

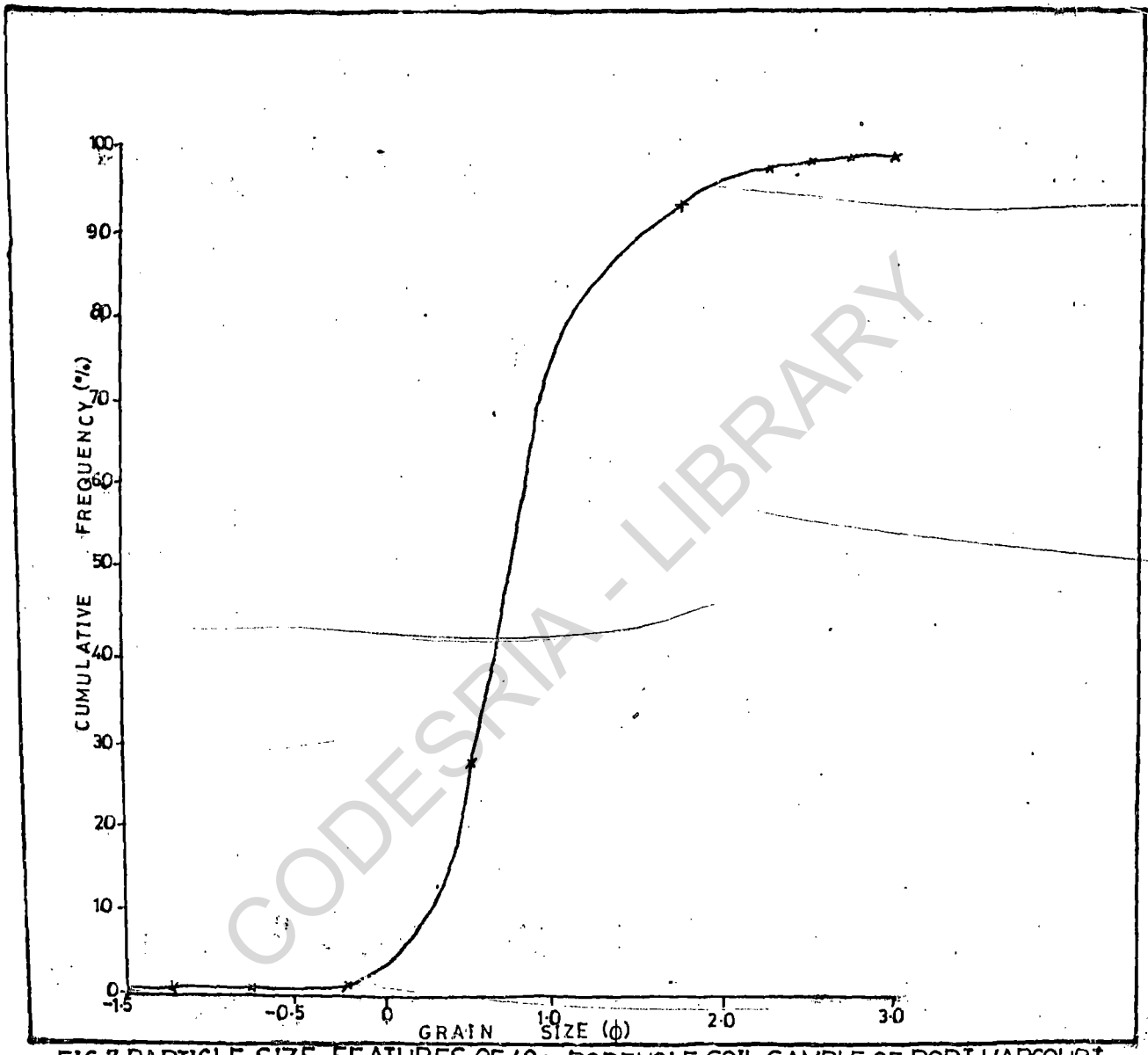

FIG. 7. PARTICLE SIZE FEATURES OF 40m BOREHOLE SOIL SAMPLE OF PORT HARCOURT AND ENVIRONS. (Source: Fieldwork, 1993).

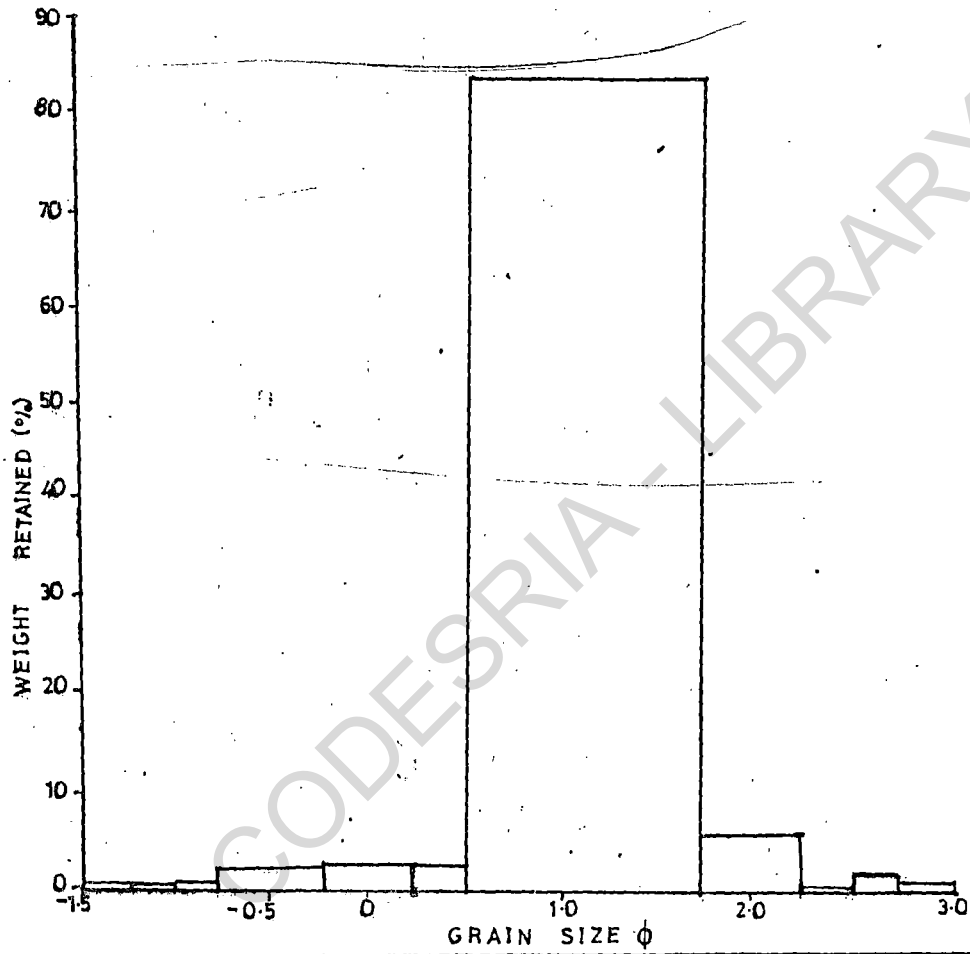

FIG.8. GRAIN SIZE FEATURES OF 40m. BOREHOLE SOIL SAMPLE OF PORT HARCOURT AND ENVIRONS (Source: Fieldwork, 1993).

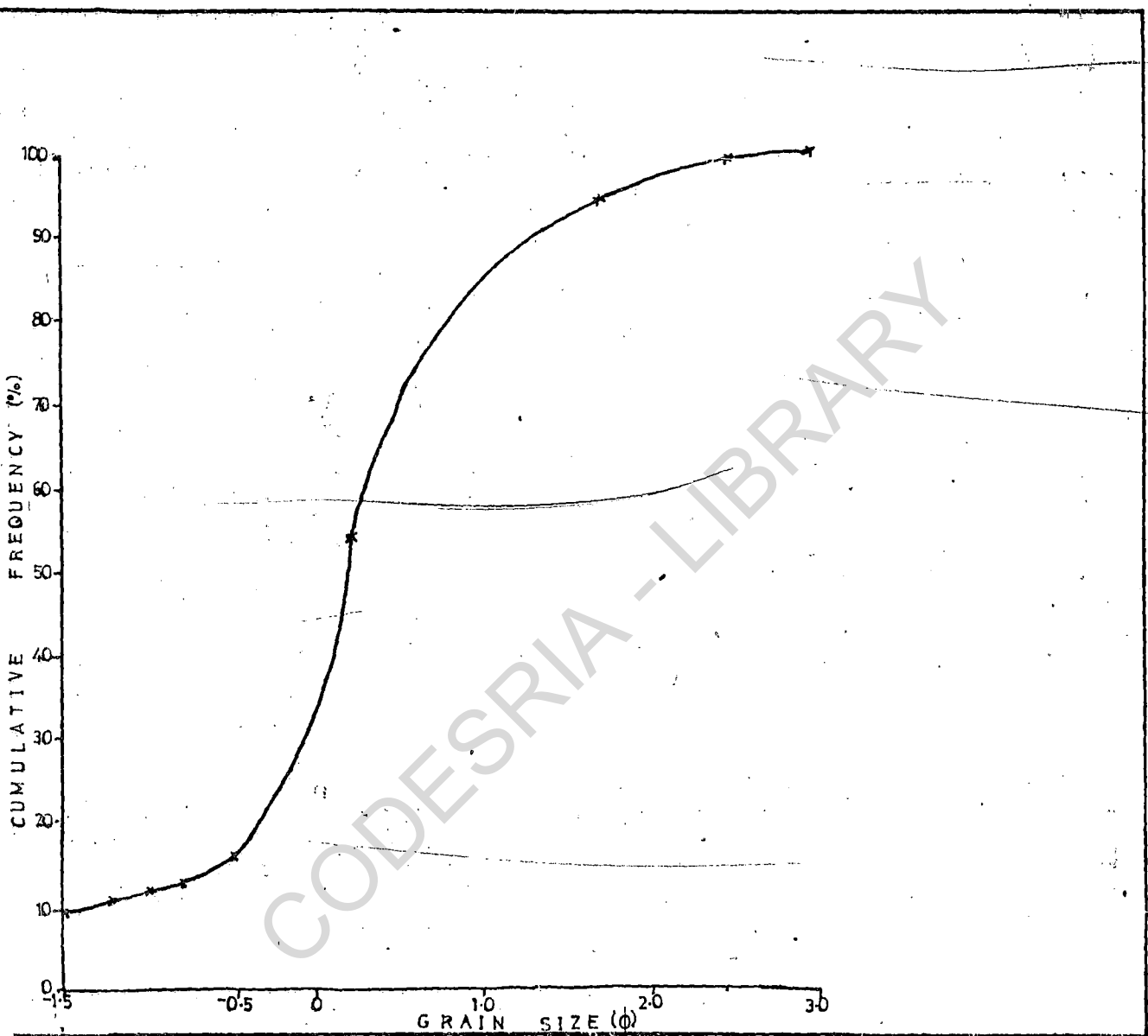

FIG.9. PARTICLE SIZE FEATURES OF 60m. BOREHOLE SOIL SAMPLE OF PORT HARCOURT AND ENVIRONS. (Source: Fieldwork, 1993).

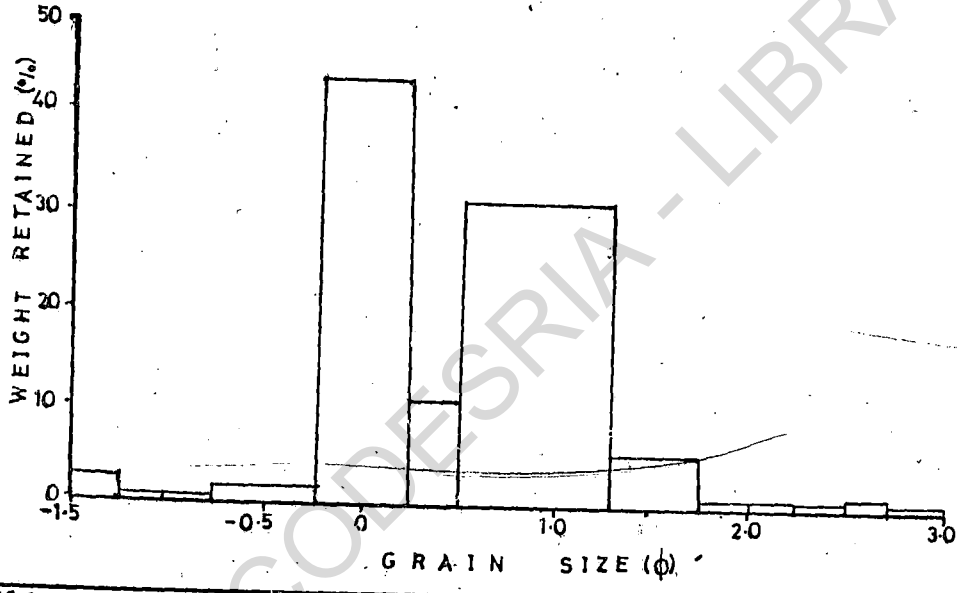

FIG.10. GRAIN SIZE FEATURES OF 60m BOREHOLE SOIL SAMPLE OF PORT HARCOURT AND ENVIRONS (Source: Fieldwork, 1993).

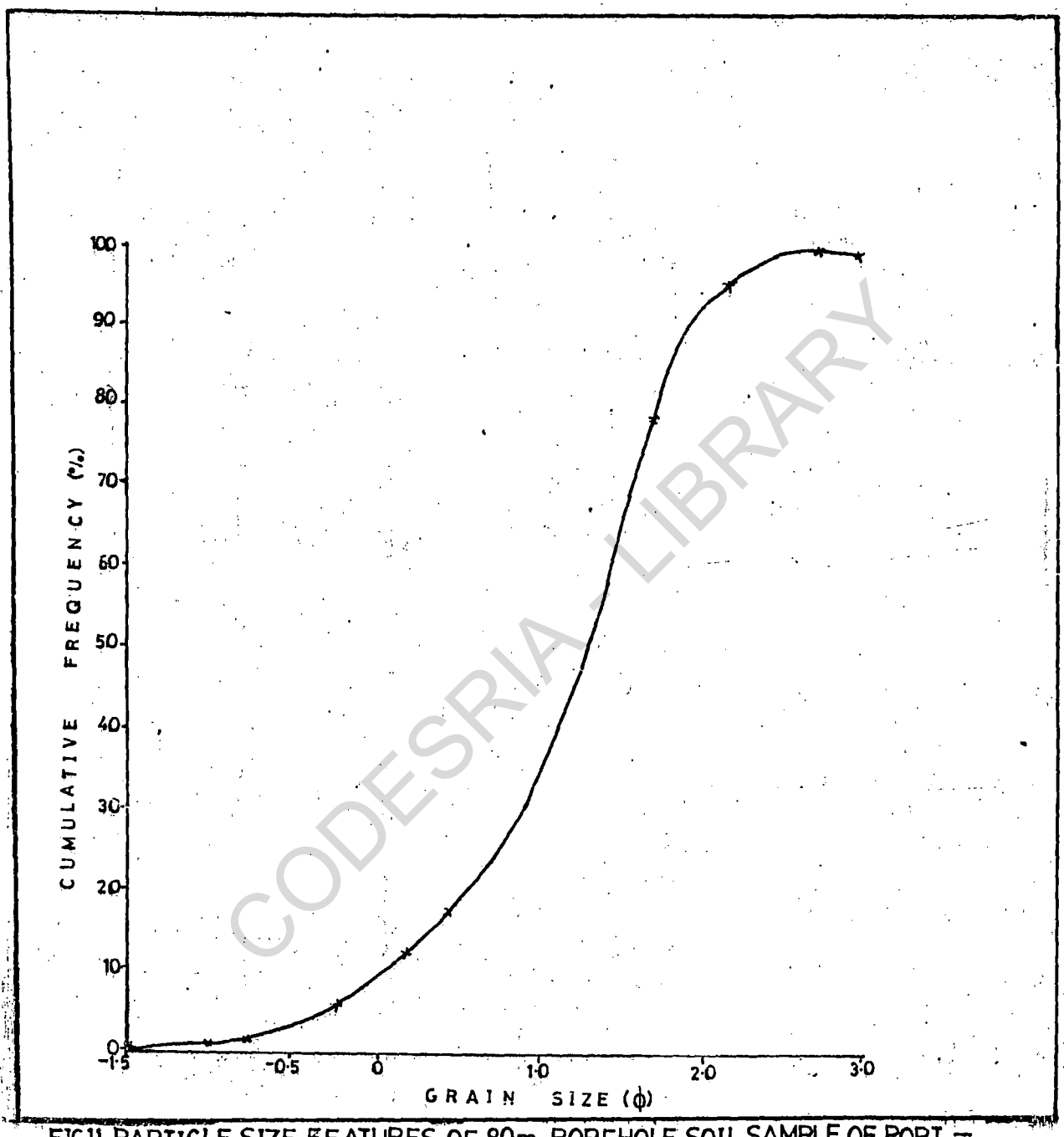

FIG.11. PARTICLE SIZE FEATURES OF 80m. BOREHOLE SOIL SAMPLE OF PORT – HARCOURT AND ENVIRONS.(Source: Fieldwork, 1993).

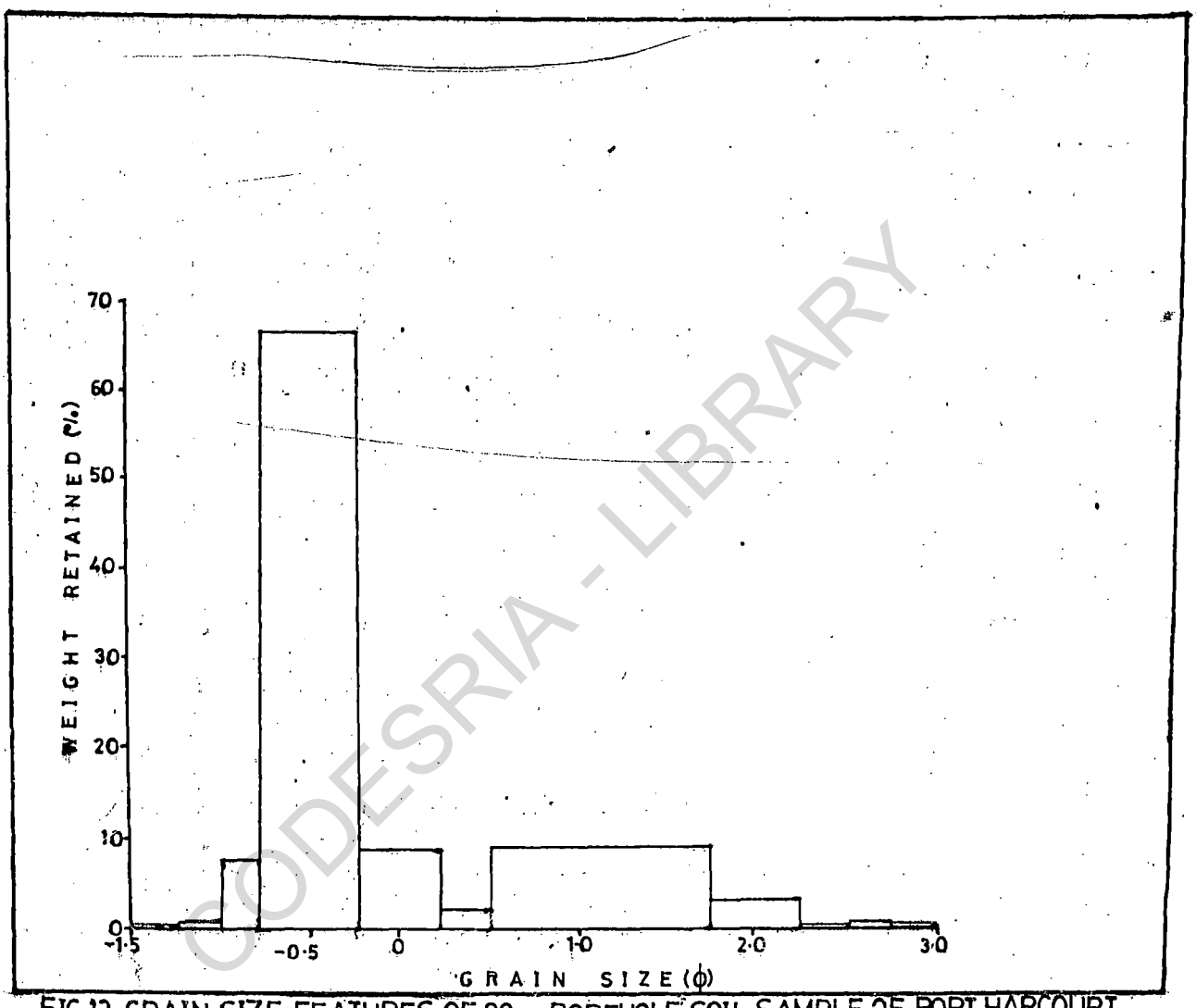

FIG.12. GRAIN SIZE FEATURES OF 80m. BOREHOLE SOIL SAMPLE OF PORT HARCOURT AND ENVIRONS. (Source: Fieldwork, 1993).

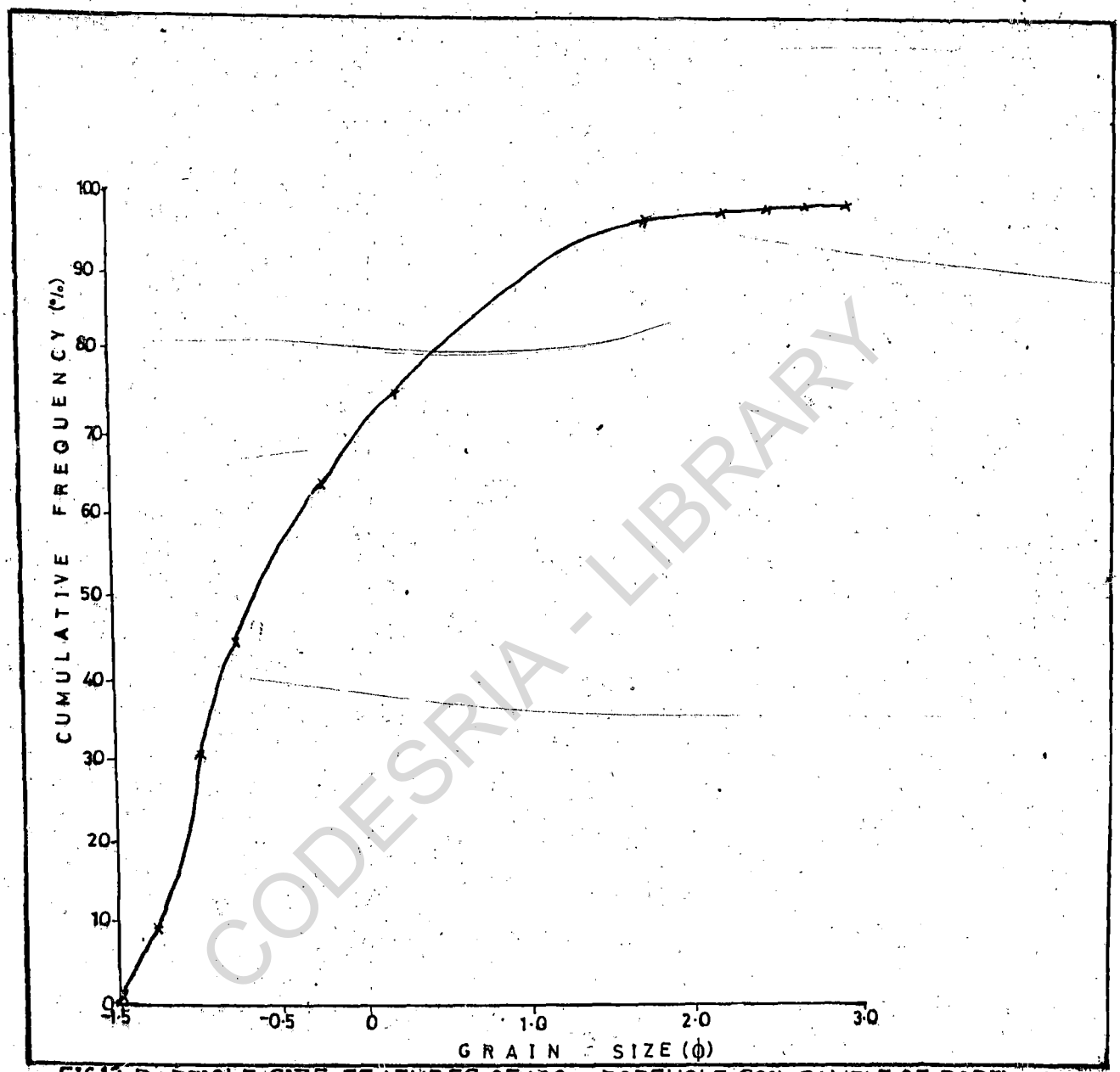

FIG13. PARTICLE SIZE FEATURES OF 100m. BOREHOLE SOIL SAMPLE OF PORT HARCOURT AND ENVIRONS (Source: Fieldwork, 1993).

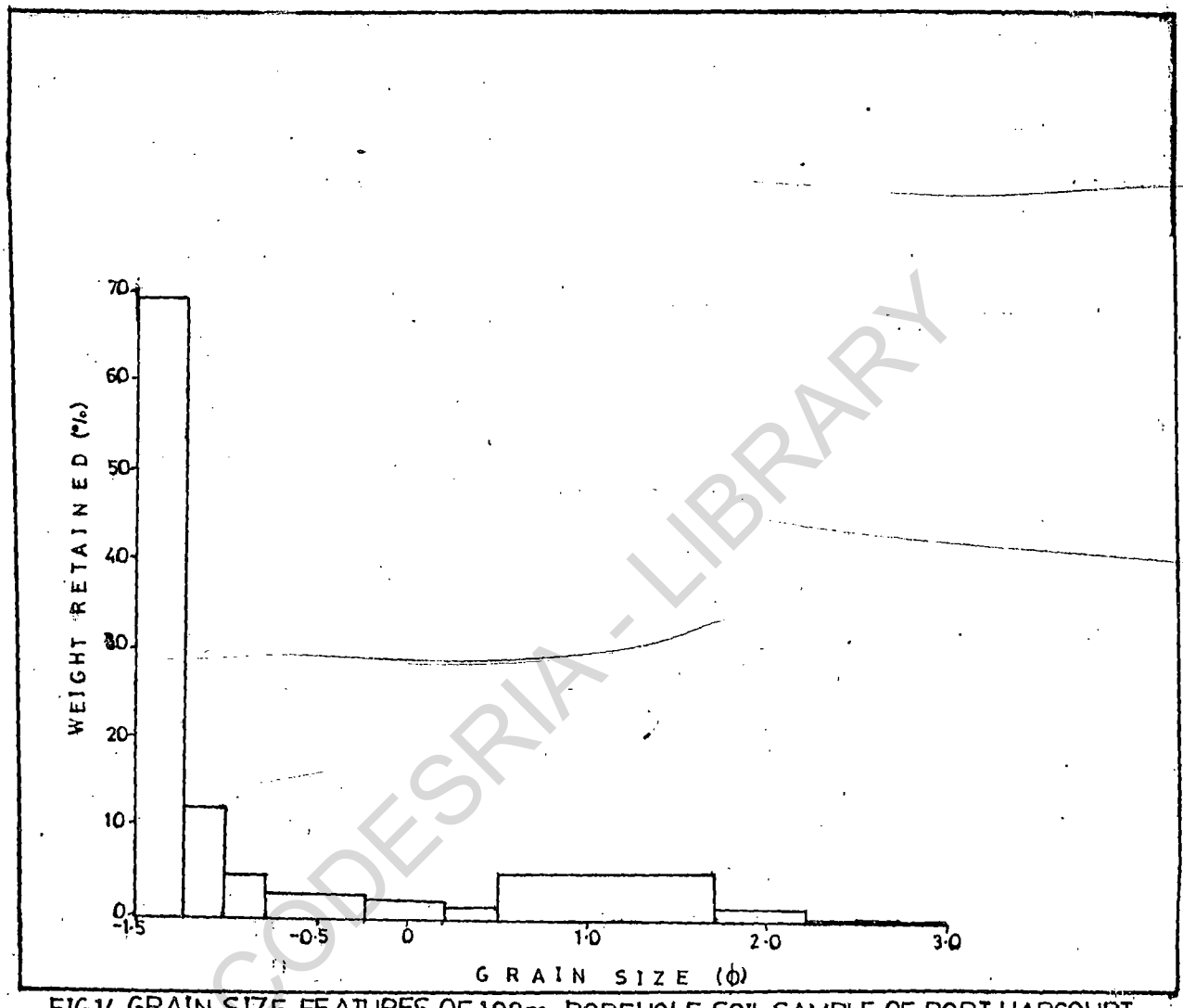

FIG.14. GRAIN SIZE FEATURES OF 100m. BOREHOLE SOIL SAMPLE OF PORT HARCOURT AND ENVIRONS (Source: Fieldwork, 1993).

In summary, from the results of the geochemical and physical characteristics of the 3 Sampled boreholes (Appendix H), it is observed that none of the boreholes was significantly polluted by petroleum oil spills considering the level of hydrocarbon detected in the boreholes. However, this does not disprove the fact that transient oil pollution does not significantly affect the water boreholes since hydrocarbon immobilization in the presence of aquatic micro-organisms is on a continual basis.

4.4 SOCIO-ECONOMIC STUDIES

Family Size and Marital Status

About 76% of the total respondents had at least six (6) children. On the average the percentage of households with 3-5 children was about 19% while only about 6% had 1-2 children. The mean family size per household including the extended family members was found to be ten (10) people. These consists of a husband, wife/wives, children and extended family members. The survey showed that 94% of them were married and only 6% single (Table 19).

Table 19: Distribution of Respondents According to Family Size and Marital Status

Variable	Frequency	Percentage
No. of Children		
Nil	0	0
1 - 2	22	5.5
3 - 5	76	19.0
6 and above	302	75.5
Marital Status		
Single	24	6.0
Married	376	94.0
Total (N)	400	

Source: Fieldwork.

Sex and Age

The results of the study showed that 89% of the respondents were males and 21% of them females. These were all household husband and wives respectively. With respect to their age distribution, 48% of the interviewed inhabitants of the 6 communities were 30yrs and under; 23% were between 31-35 yrs. while 22% of them were of the age range of 36-45yrs. Only 2% of them respectively were between 46-55 and 56-65yrs. However, 3% were found to be 66yrs. and above (Table 20).

Table 20: Distribution of Households According to their Ages

Age Range	Frequency	Percentage
30yrs. and Under	192	48.0
31-35	92	23.0
36-45	88	22.0
46-55	8	2.0
56-65	8	2.0
66 and over	12	3.0
Total	400	100.0

Source: Fieldwork

Education and Social Status

The study revealed that 34% of the inhabitants of the 6 communities have no formal education. However, 22% attempted primary 1-5 while 25% have their First School Leaving Certificate (FSLC) or completed their primary education. Five percent of the respondents had incomplete Secondary Education while 9% had West African School Certificate (WASC). Only 5% of them had post Secondary Education (Table 21).

Table 21: Distribution of Respondents According to Educational Level

Variable	Frequency	Percentage
No formal education	134	34.0
Primary 1-5	90	22.0
FSLC	100	24.0
Secondary 1-4	20	5.0
WASC	36	9.0
Post Secondary	10	5.0
Total	400	100.0

Source: Fieldwork

Thus most of the inhabitants of the 6 communities are illiterate or at best of low education.

Generally, social amenities or infrastructure were found to be thinly developed in the communities, except in one Elelenwa. In other Communities there are no road networks linking the villages, except for the major ones liking the communities themselves and which was provided by the Shell Petroleum Development Company (SPDC). However, it was discovered that Shell access roads to their oil locations (fields) have in no small measure assisted in the development of economic activities in all the Six communities investigated.

On the other hand Shell have provided pipe-borne water to all the communities, except that the accessibility to some of these puplic taps (by some sections of the communities) is quite discouraging.

However, in general, it was discovered that Shell has done much more than any other segment of the wider society in the development of the existing physical and social infrastructure in the 6 communities investigated. Apart from roads and piped water, they have built at least one secondary school in each of the communities in addition to several primary schools, health centres, and have assisted several indigenes of the communities with monetary grants especially those involved in agricultural and fishing activities.

Agricultural Production

The major occupation of the communities was found to be farming or agriculture. This involves crop and livestock production.

Land Ownership

In the Communities, land is considered the most important productive resource for agriculture. Modes of land acquisition/ownership include family, lease, purchase, pledge and community. From the survey, 43% of the people acquired their land through family inheritance, 165% by leasehold, and 15.5% through purchase. Furthermore, 12% of the respondents said their land source was through pledge while 13% of them depended on community lands. Land-ownership through gift was found to be absent in the area. The most important source of land is family land (Table 22).

Table 22: Distribution of Respondents According to Pattern OF Land Ownership

Source of Land	Frequency	Percentage
Family	172	43.0
Lease	66	16.5
Community	52	13.0
Gift	0	0.0
Purchase	62	15.5
Pledge	48	12.0
Total	400	100.0

Source: Fieldwork

Most of the field holdings were found to be upland. On the average, most farmers owned 3-6 plots of land. About 48% of them farmed 2-5 ha. of upland fields each.

Crop Production: Cropping Systems

The Cropping Systems prevalent in the Communities are mixed cropping and intercropping. These are employed for the arable crops. However, mono-cropping is also practised especially for the tree crops, such as banana, coconut and cocoa. The study showed that about 70% of the farmers adopted mixed cropping systems and 23% intercropping. The remaining 7% of the inhabitants practise such cropping systems as relay cropping, land rotation and continuous cropping.

Crop Types and Mixtures

Broadly, the crop types include both arable and tree crops. The predominant arable crops in order of importance include yam, cassava, maize, tomato, pepper, cocoyam and groundnut. Others are pumpkin, Okro, melon, garden egg, bitter leaf and green vegetable. They are normally planted in mixtures. The common arable crop combinations in the communities were found to be: maize/cassava/melon (35%), yam/maize/vegetable/melon (28%) and yam/maize/vegetable (15%). The figures in parenthesis indicate the proportion of farmers that adopt different crop mixtures.

Major tree crops grown are oil palm, citrus, bread-fruit, kola-nut, mango and coconut. Others include banana, plantain and african pear.

Farming Practices and Use of Inputs

Land clearing, tillage practices, zero tillage, among others, are some of the farm practices in the area. For land clearing, 67% of the farmers adopt clearing/burning, 20% clearing and 13% stumping. With respect to tillage practices, 93% do moulding and 7% ridging especially for yam, cassava and cocoyam. Zero tillage is employed for such crops as banana/plantain, and vegetables. However, minimum tillage were also practised for banana/plantain, and maize.

Implements used in agricultural production in the area include matchet, spade, hoe, axe, watering can and shovel. Crop production is completely dependent on rain-fed system.

Livestock and Fish Farming

The dominant species of livestock in the communities are chicken, goats and sheep. Livestock distribution in the area are as shown in Table 23.

Table 23: Distribution of Farmers According to Livestock Species Owned

Livestock Species	Frequency	Percentage
Rabbit	0	0.0
Sheep	76	19.0
Cattle	0	0.0
Goat	112	28.0
Pigs	24	6.0
Turkey	16	4.0
Ducks	8	2.0
Dogs	24	6.0
Chicken	140	35.0
Total	400	100.0

Source: Fieldwork.

Livestock husbandry systems found in the area are the intensive systems. The method used depends on the type of stock. Pig is mainly reared by the intensive method; sheep and goats by the semi-intensive system. Chicken and ducks are managed by the free-range or semi-intensive system. About 72% of the households did not own any of the species of livestock. 5% only owned one type of stock, 1% two types and about 2% owned 3-5 types while 19% owned up to 5 different species.

Fish production is essentially done to provide family income, employment as well as for consumption. Equipment used for fishing include net, hook, calabash, water pumps and engine/motor for fish ponds. Buckets and tins are also used for draining water from fish ponds, lakes or streams where fishing is carried out. A fish farmer on the average realised about #200 per month in the area during the period of study.

The major problems (in order of importance) associated with live stock and fishing activities in the area are as follows: diseases, pests, bad weather, chemicals and storage facilities for fish; and high cost of fishing equipment.

PETROLEUM/OIL RELATED ACTIVITIES: BENEFICIAL AND ADVERSE HISTORICAL BACKGROUND

The survey revealed that the Shell Petroleum Development Company which produce oil in the 6 communities studied, started operation in the communities between 1958 and 1965. The order of development is as follows, Olubiri Field, (Olubiri Community), Elelenwa Field (Elelenwa Community), Apara Field (Apara Community), Ebubu Field (Ebubu Community), Korokoro Field (Korokoro Community), and Alakiri Field Alakiri Community).

BENEFICIAL IMPACTS

Although SPDC acquired all the lands (Fields) where oil was discovered in the communities invlved, nevertheless, reasonable financial compensations were paid to the people and communities affected.

And this has assisted those communities in the development of their educational and social infrastructures. Subsequently SPDC since inception of their petroleum production activities in the area has stepped up her financial assistance to the development of the communities in diverse ways. Figure 15 summarizes graphically the contributions of SPDC to the development of the 6 communities investigated. The amenities found in the graph depics amenities introduced by SPDC between the years 1985 and 1993 only.

From the graph, it can be observed that Shell has made an impact in the development and provision of piped water to all the Communities except one - Alakiri. Again, she has positively made an impact in the development of educational infrastructures in all the communities, and has gone further to provide a modern market and hospital equipment to Elelenwa and Korokoro Communities respectively.

OTHER IMPACTS OF OIL PRODUCTION IN THE COMMUNITIES

ADVERSE IMPACTS

The impacts/effects of oil production by Shell Petroleum Development Company in the area are summarised in Table 24 overleaf.

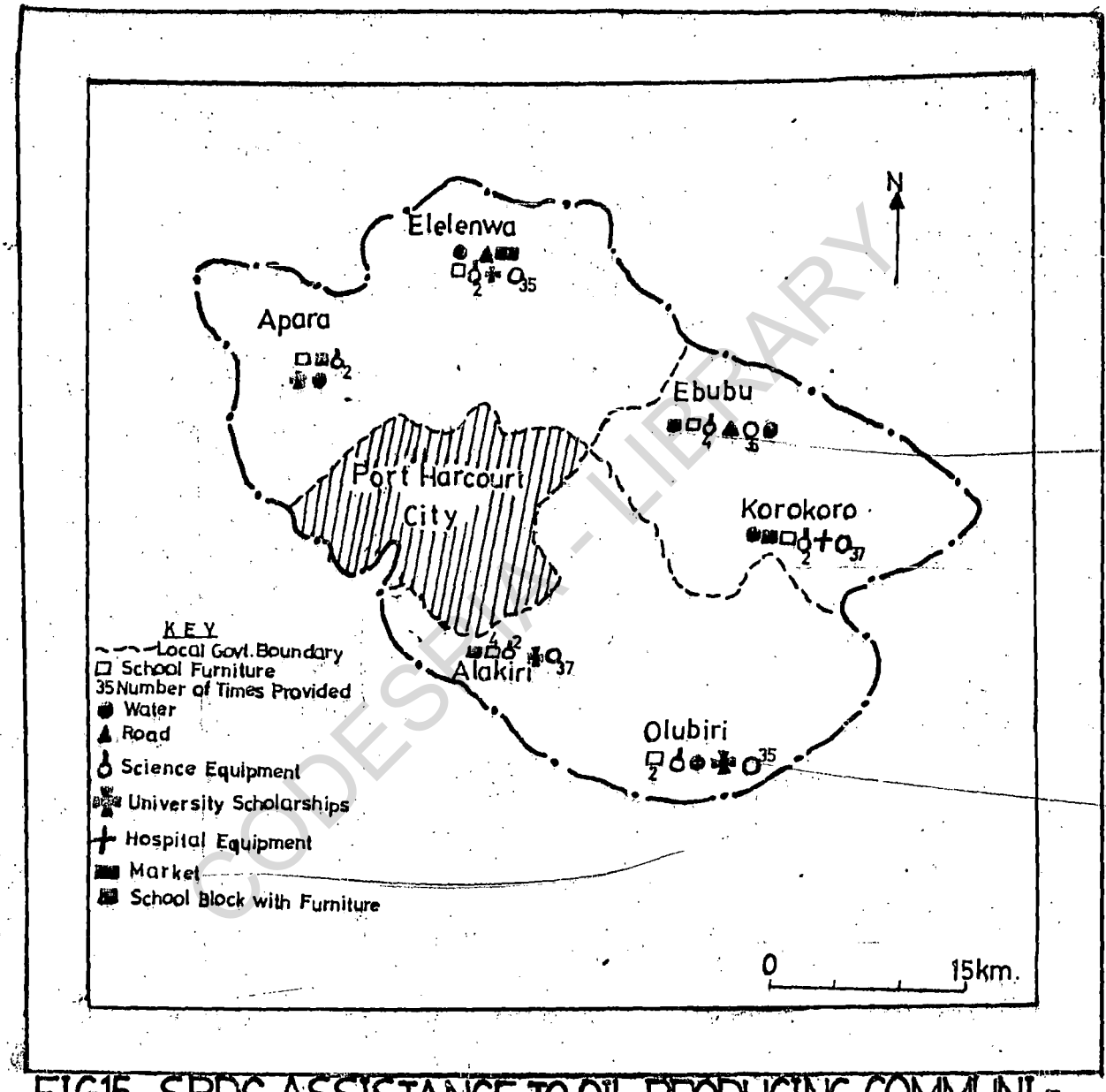

FIG.15. SPDC ASSISTANCE TO OIL PRODUCING COMMUNITIES IN PORT HARCOURT AND ENVIRONS (1985-1993).
(Source: Fieldwork, 1993).

Table 24: Problems of Oil Production in Elelenwa, Aggrey, Alakiri, Ebubu, Korokoro, and Olubiri Communities

Problems	Number of Respondents	Percentage
Occupation of land space by oil pipes and burrow-pits	384	96.0
Destruction of arable land through oil spillage	374	93.5
Death and reduced growth of vegetation, crops and economic trees	368	92.0
Discomfort from heat and vibrations	348	87.0
Health problems e.g. termination of pregnancies, sudden deaths	350	87.5
Pollution of water through oil spillage, production of tastes and odours, as well as colour change	380	95.0
Death and/or decreased population of fish and other aquatic organisms	352	88.0
Damage to houses zinc rust, wall cracks due to vibration	164	41.0
Air pollution with dust and smoke	368	92.0
Spread of insects and mosquitoes	10	2.5
Decreased livestock and fish population due to chemical poisoning	376	94.0
Total*	3,474	868.5

*Total is more than 400 due to multiple responses.

Source: Fieldwork.

The above percentage responses to the various problems created by Shell operations in the area is indicative of a significant degree of nagative impact of these operations on the people. These impacts are as follows; (as observed by the researcher).

Impacts on the Environment:

It was observed during the survey that the laying of pipes, Shell access roads, and burrow pits occupied agricultural lands, fish ponds and land spaces for infrastructural development. Excessive heat produced from the flow-stations withered most of the vegetation (especially palm trees and raffia palms) around.

Effects on Agricultural Production:

Most of the vegetables, crops and economic trees affected by recent oil spills show signs of scorching; yellowing and shedding of leaves, stunted growth and death. It is possible that oil on the leaves of plants interfered with their functioning by reducing photo-synthesis and transpiration. Animals e.g. sheep, goats, and poultry etc. die of excessive heat, chemical poisoning and water pollution from ponds contaminated by recent spills.

Effects on Water Resources:

Water quality was found to be altered through the impactation of dark red or blackish colour and objectionable odour, the presence of turbidity and oil films.

It was reported by several of the inhabitants of the Communities that most fishes cought from polluted streams are often unpalatable and show signs of reduced growth and reproductive performance and consequently decreased population.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

From the results of our various analyses, we conclude that the objectives for setting up this research project have been attained, judging from the results of our field observations, laboratory analysis of samples collected and other investigations carried out during the course of this work.

Accordingly, there is evidence of oil pollution; emanating from several oil spill incidences within our study area. And these incidences resulted from several causes, such as pipeline failures due to corrossion and faulty construction, faulty flow station operations, sabotage and theft of oil production equipment, well heads malfunctioning and several engineering faults within flow stations.

The evidence of the pollution is clear in the levels of oil obtained from soil samples, water samples, nature and biomass of the vegetation, soil and water microbiology, and socio-economic surveys.

The area of major or primary impact is around the flow stations and oil delivery lines of Elelenwa Field (PHNT) and Olubiri Field (PHST). The impact in these segments is particularly observed in the soil samples up to a depth of 30 centimeters, and between 150m to 250m from spill points.

5.2 RECOMMENDATIONS

From the above conclusions and summary of our results, we recommend the following measures for the management and control of pollution from oil spillages emanating from petroleum production activities:

1. Oil industries need to augment their efforts to ensure significant reduction of oil spills by tackling the problem directly from the various sources of oil spills, through the identification of their immediate causes. Such prevalent causes, as pipe line failures, and faulty flowstation operations need to be addressed very seriously, since this constitute over 80% of all oil spillages recorded in most studies including the present study. And since pipeline corrossion is the major cause of pipeline failures efforts, therefore, should be made towards the introduction of state-of-the-art technology in pipeline laying. Therefore, an urgent need has arisen to ensure the replacement of all existing and worn-out metallic pipes with the new "high pressure-super-reinforced poly-vinyl-chloride (PVC) pipes, as is now widely used in several pollution conscious advanced countries, as U.S.A., Canada, Sweden and Norway."
2. In the interim an effective "through pipeline" monitoring team need to be set up (by all oil companies) - whose job will be to constantly monitor both the internal and external conditions of their oil pipelines, by utilizing or employing the "instrumented inspection tool" technique.

This will go a long way in reducing or checking the corrossion of pipe lines through the replacement of worn-out and antiquated ones.

3. Strick adherence to and implementation of the National Guidelines and Standards for the petroleum industry for effective oil waste management practices need to be carried out by all oil producing companies, since the generation and disposal of these harmful wastes is more on a continual and regular basis than the oil spillages. These guidelines and standards have adequate provision for the collection, storage, treatment, and recycling of waste oils and other effluents.
4. Baseline studies need to be carried out by every oil company especially before the opening up of new oil fields since this will go a long way in helping to sensitize and synthesise all important and sensitive environmental factors needed to be addressed before, during, and after the expoitation of such oil fields. Such baseline studies would contribute immensely to the enhancement of the quality of the environment through the regular monitoring of relevant environmental parameters to regulate their qualities by the utilization of a multi-disciplinary approach, and in addition to the application of state-of-the-art technologies.
5. A functional and effective National Oil Spill Contingency Plan should be put in place to ensure that up-to-date technologies are applied during oil spill emergencies. And coordinated emergency relief teams from the major oil companies need to be put in place to assist in particular the smaller oil companies who might not

alone cope with major oil spills from their activities. The NNPC could coorfinate this team to ensure effectiveness and compliance.

6. Stringent efforts should be made to protect "critical habitats," such as streams, lakes, and ponds during an oil spill incidence by ensuring that no amount of oil enters into them as this could cause serious short term damage to the habitats. Also this effort should be extended to some other habitats as shoreline vegetation, which habour some endangered animal species, such as the rare African-grey-parrot found during our study.
7. Finally, all abandoned burrow or waste pits should be identified for regular clean-up and remediation by the generators of the wastes.

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APPENDIX A(1)

Physico-chemical Characteristics of Soil Samples From Port Harcourt And Environs

Transect PHNW$_1$T	Depth (Cm)	Ph	EC	THC. (PPM)	Org.C. %	PO_4 (ppm)	TOTAL N %	NH_4^+	NO_2^-	NO_3^-	Na^+	K^+	Ca^{2+}	Mg^{2+}
								(PPM)			(Meq/100g Soil)			
0	0-15	6.3	0.2	ND	1.2	14.0	0.18	5.0	0.4	13.0	0.12	0.06	0.90	1.00
	15-30	6.1	0.2	ND	0.8	14.0	0.18	5.0	0.4	13.0	0.12	0.05	0.80	0.80
50	0-15	6.6	0.1	ND	1.3	18.0	0.19	5.0	0.4	12.0	0.11	0.05	0.90	1.40
	15.30	6.2	0.1	ND	0.7	22.0	0.19	5.0	0.4	13.0	0.11	0.05	0.08	1.26
100	0-15	6.7	0.1	ND	1.2	14.0	0.08	4.0	0.4	7.0	0.09	0.05	0.95	1.58
	15-30	6.7	0.1	ND	0.8	19.0	0.10	3.0	0.2	5.0	0.10	0.04	0.70	1.21
150	0-15	6.6	0.1	ND	1.3	18.0	0.18	5.0	0.4	13.0	0.11	0.05	0.90	1.50
	15-30	6.4	0.1	ND	0.9	20.0	0.18	6.0	0.3	13.0	0.11	0.05	0.90	1.30
200	0-15	6.7	0.1	ND	1.7	14.0	0.12	7.0	1.0	32.0	0.12	0.13	2.40	2.82
	15-30	6.8	0.1	ND	1.0	20.0	0.10	8.0	0.1	10.0	0.12	0.18	1.55	1.57
250	0-15	6.6	0.1	ND	1.0	22.0	0.12	5.0	0.4	16.0	0.12	0.16	1.30	2.00
	15-30	6.7	0.1	ND	0.8	18.0	0.11	4.0	0.4	13.0	0.11	0.10	0.90	1.16
300	0-15	6.7	0.2	ND	1.0	19.0	0.10	4.0	0.1	14.0	0.10	0.12	1.50	1.66
	15-30	6.7	0.1	ND	0.9	14.0	0.10	5.0	0.2	7.0	0.12	0.07	1.20	0.50
350	0-15	6.6	0.1	ND	1.5	15.0	0.10	7.0	1.4	18.0	0.10	0.13	1.30	1.50
	15-30	6.7	0.1	ND	1.3	30.0	0.19	8.0	1.0	28.0	0.10	0.18	1.10	1.20
400	0-15	6.6	0.1	ND	1.0	23.0	0.13	5.0	0.4	18.0	0.12	0.17	1.45	2.02
	15-30	6.7	0.1	ND	0.8	17.0	0.11	3.0	0.4	13.0	0.10	0.09	0.80	1.15
450	0-15	6.6	0.1	ND	1.3	20.0	0.17	6.0	0.4	25.0	0.11	0.15	1.60	1.30
	15-30	6.7	0.1	ND	1.0	17.0	0.14	7.0	0.4	17.0	0.10	0.12	0.90	0.80
500	0-15	6.3	0.2	ND	1.2	20.0	0.19	5.0	0.4	18.0	0.12	0.05	1.60	1.07
	15-30	6.4	0.2	ND	0.8	18.0	0.11	5.0	0.4	9.0	0.11	0.06	0.80	0.52

APPENDIX A(2)

Physico-chemical Characteristics of Soil Samples From Port Harcourt and Environs

Transect PHNW$_2$T	Depth (Cm)	Ph	EC	THC (PPM)	Org.C. %	PO_4 (PPM)	TOTAL N %	NH_4^+ (PPM)	NO_2^- (PPM)	NO_3^- (PPM)	Na^+ (Meq/100g Soil)	K^+ (Meq/100g Soil)	Ca^{2+} (Meq/100g Soil)	Mg^{2+} (Meq/100g Soil)
0	0-15	6.6	0.1	ND	1.3	18.0	0.10	2.0	0.7	11.0	0.13	0.07	1.50	1.28
	15-30	6.2	0.1	ND	0.7	22.0	0.08	6.0	0.1	5.0	0.11	0.06	0.90	0.98
50	0-15	6.0	0.3	ND	1.9	21.0	0.11	6.0	0.7	9.0	0.11	0.07	1.60	2.24
	15-30	6.3	0.4	ND	0.9	24.0	0.06	3.0	0.4	9.0	0.10	0.06	0.65	1.28
100	0-15	6.3	0.1	ND	1.7	15.0	0.17	2.0	1.4	18.0	0.13	0.09	2.60	1.94
	15-30	6.4	0.1	ND	1.6	17.0	0.15	3.0	0.4	5.0	0.11	0.07	1.90	1.08
150	0-15	6.4	0.1	ND	1.2	11.0	0.06	4.0	0.5	23.0	0.10	0.06	1.55	1.32
	15-30	6.0	0.6	ND	1.0	23.0	0.12	2.0	0.2	7.0	0.09	0.06	0.90	1.18
200	0-15	6.4	0.1	ND	1.2	11.0	0.06	4.0	0.5	23.0	0.10	0.06	1.55	1.32
	15-30	6.0	0.6	ND	1.0	23.0	0.12	2.0	0.2	7.0	0.09	0.06	0.90	1.18
250	0-15	6.4	0.1	ND	1.5	17.0	0.18	3.0	0.4	0.9	0.13	0.07	1.55	1.34
	15-30	6.5	0.1	ND	1.0	16.0	0.17	4.0	0.2	4.0	0.12	0.05	1.10	0.82
300	0-15	6.4	0.1	ND	1.5	17.0	0.18	3.0	0.4	9.0	0.13	0.07	1.55	1.34
	15-30	6.5	0.1	ND	1.0	16.0	0.17	4.0	0.2	4.0	0.12	0.05	1.10	0.82
350	0-15	6.4	0.1	ND	1.2	11.0	0.06	4.0	0.5	23.0	0.10	0.06	1.55	1.32
	15-30	6.0	0.6	ND	1.0	23.0	0.12	2.0	0.2	7.0	0.09	0.06	0.90	1.18
400	0-15	6.3	0.1	ND	1.7	15.0	0.17	2.0	1.4	18.0	0.13	0.09	2.60	1.94
	15-30	6.4	0.1	ND	1.6	17.0	0.15	3.0	0.4	5.0	0.11	0.07	1.90	1.08
450	0-15	6.0	0.3	ND	1.9	21.0	0.11	6.0	0.7	9.0	0.11	0.07	1.60	2.24
	15-30	6.3	0.4	ND	0.9	24.0	0.06	3.0	0.4	9.0	0.10	0.06	0.65	1.28
500	0-15	6.6	0.1	ND	1.3	18.0	0.10	2.0	0.7	11.0	0.13	0.07	1.50	1.28
	15-30	6.2	0.1	ND	0.7	22.0	0.08	6.0	0.1	5.0	0.11	0.06	0.90	0.98

APPENDIX A(3)

Physico-Chemical Characteristics of Soil Samples from Port Harcourt and Environs

Transect $PHNE_1T$	Depth (Cm)	Ph	EC	THC (PPM)	Org.C. %	PO_4 (PPM)	TOTAL N %	NH_4^+	NO_2^-	NO_3^-	Na^+	K^+	Ca^{2+}	Mg^{2+}
								(PPM)			(Meq/100g Soil)			
0	0–15	6.0	0.1	ND	2.0	17.0	0.21	1.0	2.0	5.0	0.13	0.15	3.30	1.78
	15–30	6.2	0.1	ND	1.1	16.0	0.16	3.0	0.4	44.0	0.11	0.14	2.10	1.01
50	0–15	6.3	0.1	ND	0.7	12.0	0.11	3.0	0.7	23.0	0.11	0.10	1.85	1.28
	15–30	6.3	0.2	ND	0.4	13.0	0.06	3.0	0.5	18.0	0.12	0.06	1.20	0.60
100	0–15	6.1	0.1	ND	0.9	21.0	0.13	4.0	0.7	14.0	0.12	0.06	1.40	1.12
	15–30	6.3	0.1	ND	0.3	20.0	0.05	5.0	0.2	5.0	0.10	0.04	0.70	0.42
150	0–15	5.9	0.1	ND	0.9	14.0	0.15	3.0	0.6	23.0	0.10	0.07	1.90	1.08
	15–30	6.2	0.2	ND	0.5	15.0	0.09	3.0	1.2	32.0	0.11	0.05	0.45	0.50
200	0–15	6.1	0.1	ND	1.0	20.0	0.13	2.0	0.6	27.0	0.11	0.05	1.95	0.90
	15–30	6.3	0.2	ND	0.7	24.0	0.05	3.0	0.5	9.0	012	0.04	1.20	0.48
250	0–15	5.9	0.1	ND	0.9	14.0	0.15	3.0	0.6	23.0	0.10	0.07	1.90	1.08
	15–30	6.2	0.2	ND	0.5	15.0	0.09	3.0	1.2	32.0	0.11	0.05	0.45	0.50
300	0–15	6.3	0.1	ND	0.7	12.0	0.11	3.0	0.7	23.0	0.11	0.10	1.85	1.28
	15–30	6.3	0.2	ND	0.4	13.0	0.06	3.0	0.5	18.0	0.12	0.06	1.00	0.60
350	0–15	6.1	0.1	ND	1.0	20.0	0.13	2.0	0.6	27.0	0.11	0.05	1.95	0.92
	15–30	6.3	0.2	ND	0.7	24.0	0.05	3.0	0.5	9.0	0.12	0.04	1.20	0.48
400	0–15	6.1	0.1	ND	0.9	21.0	0.13	4.0	0.7	14.0	0.12	0.06	1.40	1.12
	15–30	6.3	0.1	ND	0.3	20.0	0.05	5.0	0.2	5.0	0.10	0.04	0.70	0.42
450	0.15	6.3	0.1	ND	0.7	12.0	0.11	3.0	0.7	23.0	0.11	0.10	1.85	1.28
	15–30	6.3	0.2	ND	0.4	13.0	0.06	3.0	0.5	18.0	0.12	0.06	1.00	0.60
500	0.15	6.0	0.1	ND	2.0	17.0	0.21	1.0	2.0	5.0	0.13	0.15	3.30	1.78
	15–30	6.2	0.1	ND	1.1	16.0	0.16	3.0	0.4	4.0	0.11	0.14	2.10	1.01

APPENDIX A(4)

Physico-Chemical Characteristics of Soil Samples from Port Harcourt and Environs

Transect PHNE$_2$T	Depth (Cm)	Ph	Ec	THC (PPM)	Org.C. %	PO_4 (PPM)	TOTAL N %	NH_4^+	NO_2^-	NO_3^-	Na^+	K^+	Ca^{2+}	Mg^{2+}
								(PPM		)	(Meq/100g Soil			)
0	0-15	6.2	0.1	ND	0.1	1.0	0.10	5.0	0.6	10.0	0.10	0.08	2.00	1.16
	15-30	6.4	0.1	ND	0.6	6.0	0.05	3.0	0.5	2.0	0.09	0.05	1.30	0.73
50	0-15	6.1	0.2	ND	0.7	14.0	0.10	9.0	0.2	17.6	0.10	0.09	1.25	0.86
	15-30	6.1	0.1	ND	0.6	11.0	0.08	10.0	0.2	22.3	0.10	0.05	0.70	0.42
100	0-15	6.3	0.1	ND	1.5	16.0	0.11	2.0	1.9	10.0	0.10	0.10	3.15	1.16
	15-30	6.4	0.1	ND	0.6	19.0	0.12	4.0	1.4	12.0	0.09	0.07	1.40	0.38
150	0-15	6.1	0.2	ND	0.7	16.0	0.10	10.0	0.2	20.0	0.10	0.08	1.16	0.80
	15-30	6.1	0.1	ND	0.6	14.0	0.07	11.0	0.2	16.0	0.08	0.06	0.80	0.50
200	0-15	6.4	0.1	ND	0.9	12.0	0.11	6.0	0.2	12.0	0.08	0.07	1.00	0.61
	15-30	6.2	0.1	ND	0.6	18.0	0.12	9.0	0.2	19.0	0.10	0.06	0.70	0.50
250	0-15	6.4	0.2	ND	1.0	10.0	0.12	4.0	1.00	32.0	0.10	0.07	2.30	0.10
	15-30	6.5	0.1	ND	0.5	20.0	0.11	4.0	1.20	44.0	0.10	0.05	1.50	0.47
300	0-15	6.3	0.1	ND	1.5	18.0	0.10	6.0	1.80	26.0	0.10	0.10	3.20	1.18
	15-30	6.2	0.1	ND	0.5	16.0	0.12	9.0	0.20	39.0	0.10	0.05	0.50	0.46
350	0-15	6.4	0.1	ND	0.9	12.0	0.11	5.0	0.20	32.0	0.08	0.07	1.00	0.59
	15-30	6.2	0.1	ND	0.5	16.0	0.12	9.0	0.20	39.0	0.10	0.05	0.50	0.46
400	0-15	6.1	0.2	ND	0.7	13.0	0.10	9.0	0.20	26.0	0.10	0.09	1.25	0.86
	15-30	6.1	0.1	ND	0.6	10.0	0.08	10.0	0.20	23.0	0.10	0.05	0.50	0.37
450	0-15	6.4	0.2	ND	1.0	16.0	0.25	6.0	1.0	30.0	0.10	0.19	2.30	0.20
	15-30	6.5	0.1	ND	0.7	20.0	0.20	8.0	1.10	42.0	0.10	0.15	1.80	0.42
500	0-15	6.2	0.1	ND	1.0	11.0	0.10	5.0	1.7	10.0	0.10	0.09	1.25	1.16
	15-30	6.4	0.1	ND	0.8	16.0	0.07	9.0	1.3	18.0	0.08	0.06	0.90	0.80

APPENDIX A(3)

Physico-Chemical Characteristics of Soil Samples from Port Harcourt and Environs

Transect. PHST	Depth (Cm)	Ph	Ec	THC (PPM)	Org.C. %	PO_4 (PPM)	TOTAL N %	NH_4^+	NO_2^-	NO_3^-	Na^+	K^+	Ca^{2+}	Mg^{2+}
								(PPM)			(Meq/100g Soil)			
0	0–15	5.9	0.2	860	1.1	18.0	0.17	6.0	0.70	3.0	0.09	0.11	0.90	0.64
	15–30	6.1	0.1	720	0.8	12.0	0.17	8.0	0.20	18.0	0.09	0.07	0.45	0.43
50	0–15	6.0	0.1	750	1.1	15.0	0.20	4.0	0.20	16.0	0.10	0.12	1.25	0.74
	15–30	6.1	0.1	700	0.9	16.0	0.20	6.0	2.06	14.0	0.10	0.07	0.35	2.04
100	0–15	6.0	0.1	417	1.4	10.0	0.25	4.0	0.10	19.0	0.10	0.07	0.40	0.41
	15–30	5.9	0.1	364	0.9	19.0	0.20	7.0	0.00	18.0	0.10	0.06	0.25	0.20
150	0–15	5.8	0.1	180	1.2	10.0	0.08	4.0	0.00	11.0	0.11	0.07	0.50	0.33
	15–30	5.7	0.1	120	0.8	13.0	0.06	5.0	0.00	19.0	0.10	0.05	0.25	0.17
200	0–15	6.0	0.1	86	1.4	10.0	0.25	4.0	0.10	19.0	0.10	0.07	0.40	0.41
	15–30	5.9	0.1	78	0.9	19.0	0.20	7.0	0.00	18.0	0.10	0.06	0.25	0.20
250	0–15	5.6	0.2	18	1.3	15.0	0.08	6.0	0.20	14.0	0.10	0.06	0.30	0.18
	15–30	5.7	0.1	10	1.0	10.0	0.06	8.0	2.40	16.0	0.10	0.05	0.25	0.35
300	0–15	5.8	0.1	ND	1.4	10.0	0.12	6.0	0.00	11.0	0.11	0.07	0.50	0.33
	15–30	5.7	0.1	ND	0.9	12.0	0.10	7.0	0.00	19.0	0.10	0.05	0.25	0.17
350	0–15	5.3	0.3	ND	1.9	17.0	0.11	3.0	0.40	81.0	0.12	0.17	0.55	1.27
	15–30	5.4	0.2	ND	1.4	10.0	0.08	4.0	0.20	36.0	0.12	0.13	0.50	0.33
400	0–15	6.0	0.2	ND	1.4	15.0	0.20	6.8	1.30	14.0	0.10	0.08	1.00	0.38
	15–30	6.1	0.1	ND	1.0	10.0	0.20	8.0	2.40	16.0	0.10	0.06	0.60	0.58
450	0–15	5.7	0.1	ND	2.6	14.0	0.11	12.0	0.70	41.0	0.10	0.26	0.80	1.23
	15–30	5.6	0.1	ND	2.0	17.0	0.10	17.0	0.30	23.0	0.09	0.12	0.30	0.17
500	0–15	4.8	0.3	ND	5.3	10.0	0.23	15.0	0.30	17.0	0.10	0.19	0.55	0.24
	15–30	5.3	0.1	ND	3.5	13.0	0.15	16.0	0.50	18.0	0.11	0.10	0.35	0.01

APPENDIX A(6)

Physico-Chemical Characteristics of Soil Samples from Port Harcourt and Environs

Transect PHSW$_1$T	Depth (cm)	Ph	Ec	THC (PPM)	Org.C. %	PO_4 (PPM)	TOTAL N %	NH_4^-	NO_2^-	NO_3^-	Na^+	K^+	Ca^{2+}	Mg^{2+}
								(PPM)			(Meq/100g Soil)			
0	0-15	5.9	0.1	ND	1.4	38.0	0.11	7.0	1.1	59.0	0.08	0.20	3.85	2.08
	15-30	5.9	0.2	ND	0.5	63.0	0.09	7.0	0.2	9.0	0.07	0.21	1.25	0.95
50	0-15	5.9	0.1	ND	1.4	38.0	0.11	7.0	1.1	59.0	0.08	0.20	3.85	2.08
	15-30	5.9	0.2	ND	0.5	63.0	0.09	7.0	0.2	9.0	0.07	0.21	1.25	0.95
100	0-15	6.0	0.1	ND	1.1	60.0	0.11	8.0	0.7	99.0	0.07	0.11	2.18	1.24
	15-30	5.7	0.2	ND	0.2	46.0	0.09	6.0	0.1	16.0	0.08	0.07	1.00	0.55
150	0-15	6.0	0.1	ND	1.1	60.0	0.11	8.0	0.7	99.0	0.07	0.11	2.15	1.24
	15-30	5.7	0.2	ND	0.2	46.0	0.09	6.0	0.1	16.0	0.08	0.07	1.00	0.55
200	0-15	6.0	0.1	ND	0.9	53.0	0.11	7.0	0.1	72.0	0.07	0.07	0.85	0.08
	15-30	5.3	0.2	ND	0.6	52.0	0.10	6.0	0.0	14.0	0.07	0.07	0.55	0.38
250	0-15	6.0	0.1	ND	0.9	53.0	0.11	7.0	0.1	72.0	0.07	0.07	0.85	0.08
	15-30	5.3	0.2	ND	0.6	52.0	0.10	6.0	0.0	14.0	0.07	0.07	0.55	0.38
300	0-15	6.0	0.1	ND	1.1	60.0	0.11	8.0	0.7	99.0	0.07	0.11	2.15	1.24
	15-30	5.7	0.2	ND	0.2	46.0	0.09	6.0	0.1	16.0	0.08	0.07	1.00	0.55
350	0.15	5.5	0.1	ND	1.0	78.0	0.11	5.0	3.1	90.0	0.08	0.12	1.90	0.64
	15-30	5.5	0.2	ND	0.2	54.0	0.09	5.0	0.5	11.0	0.07	0.06	0.50	0.06
400	0-15	5.6	0.1	ND	1.3	12.0	0.08	6.0	0.5	108.0	0.08	0.13	1.50	0.42
	15-30	5.4	0.2	ND	0.7	27.0	0.08	7.0	0.2	27.0	0.06	0.08	0.35	0.13
450	0-15	5.6	0.1	ND	1.3	12.0	0.08	6.0	0.5	108.0	0.08	0.13	1.50	0.42
	15-30	5.4	0.2	ND	0.7	27.0	0.08	7.0	0.2	27.0	1.06	0.08	0.35	0.13
500	0-15	5.5	0.1	ND	1.0	78.0	0.11	5.0	3.1	90.0	0.08	0.12	1.90	0.64
	15-30	5.5	0.2	NB	0.2	54.0	0.09	5.0	0.5	11.0	0.07	0.06	0.60	0.06

APPENDIX A(7)

Physico-Chemical Characteristics of Soil Samples from Port Harcourt and Environs

Transect. PHSW$_2$T	Depth (Cm)	Ph	Ec	THC (PPM)	Org.C. %	PO_4 (PPM)	TOTAL N %	NH_4^- (	NO_2^- PPM	$NO3^-$)	Na^+ (	K^+ Meq/100g Soil	Ca^{2+}	Mg^{2+})
0	0-15	5.6	0.1	ND	1.1	86.0	0.09	5.0	0.7	70.0	0.07	0.12	0.80	0.08
	15-30	5.2	0.1	ND	0.6	80.0	0.10	4.0	0.3	18.0	0.07	0.07	0.40	0.44
50	0-15	5.5	0.1	ND	1.4	12.0	0.11	5.0	1.4	16.0	0.08	0.18	2.10	1.28
	15-30	5.5	0.3	ND	0.7	47.0	0.10	7.0	0.4	36.0	0.07	0.12	0.60	0.10
100	0-15	5.8	0.1	ND	1.1	80.0	0.07	8.0	0.4	65.0	0.08	0.13	1.35	0.05
	15-30	5.5	0.2	ND	0.5	22.0	0.09	8.0	0.5	16.0	0.07	0.09	0.55	0.30
150	0-15	5.6	0.2	ND	1.1	22.0	0.11	6.0	0.5	99.0	0.08	0.15	0.00	0.34
	15-30	5.3	0.3	ND	0.9	12.0	0.09	6.0	0.5	27.0	0.07	0.10	0.45	0.13
200	0-15	5.7	0.1	ND	2.0	52.0	0.13	4.0	0.2	42.0	0.07	0.09	0.75	0.20
	15-30	5.4	0.2	ND	1.0	60.0	0.11	6.0	0.2	18.0	0.06	0.04	0.30	0.34
250	0-15	5.8	0.1	ND	1.1	80.0	0.07	8.0	0.4	65.0	0.08	0.13	1.35	0.05
	15-30	5.5	0.2	ND	0.5	22.0	0.09	8.0	0.5	16.0	0.07	0.09	0.55	0.30
300	0-15	5.5	0.1	ND	1.4	12.0	0.11	5.0	1.4	62.0	0.08	0.18	2.10	1.28
	15-30	5.5	0.3	ND	0.7	47.0	0.10	7.0	0.4	36.0	0.07	0.12	0.60	0.10
350	0-15	5.7	0.1	ND	2.0	52.0	0.13	4.0	0.2	45.0	0.07	0.09	0.75	0.20
	15-30	5.4	0.2	ND	1.0	60.0	0.11	6.0	0.2	18.0	0.06	0.04	0.30	0.34
400	0-15	5.6	0.1	ND	1.1	86.0	0.09	5.0	.07	70.0	0.07	0.12	0.80	0.08
	15-30	5.2	0.1	ND	0.6	80.0	0.10	4.0	0.3	18.0	0.07	0.07	0.40	0.44
450	0-15	5.4	0.2	ND	2.0	91.0	0.12	5.0	0.5	59.0	0.07	0.09	0.55	0.57
	15-30	5.2	0.2	ND	1.0	26.0	0.11	6.0	0.2	11.0	0.07	0.07	0.40	0.03
500	0-15	5.6	0.2	ND	1.4	22.0	0.11	6.0	0.5	99.0	0.08	0.15	1.00	0.34
	15-30	5.3	0.3	ND	0.9	12.0	0.09	6.0	0.5	27.0	0.07	0.10	0.45	0.13

APPENDIX A(B)

Physico-Chemical Characteristics of Soil Samples from Port Harcourt and Environs

Transect $PHSE_1T$	Depth (Cm)	Ph	Ec	THC (PPM)	Org.C. %	PO_4 (PPM)	TOTAL N %	NH_4^+ (	NO_2^- PPM	NO_3^-)	Na^+ (	K^+ Meq/100g Soil	Ca^{2+}	Mg^{2+})
0	0–15	5.6	0.1	ND	1.0	22.0	0.09	6.0	0.2	1.4	0.07	0.07	0.60	0.21
	15–30	5.6	0.1	ND	0.9	18.0	0.12	3.0	0.2	9.0	0.08	0.06	0.50	3.39
50	0–15	5.7	0.1	ND	0.7	10.0	0.05	4.0	0.4	9.0	0.09	0.07	0.70	0.17
	15–30	5.8	0.1	ND	0.7	22.0	0.07	7.0	0.5	5.0	0.09	0.05	0.45	7.12
100	0–15	5.9	0.1	ND	0.7	10.0	0.09	5.0	0.5	27.0	0.09	0.06	0.80	0.22
	15–30	6.0	0.1	ND	0.4	21.0	0.05	5.0	0.7	18.0	0.10	0.04	0.50	0.83
150	0–15	5.7	0.1	ND	1.0	21.0	0.07	6.0	0.1	14.0	0.10	0.05	0.90	1.18
	15–30	5.8	0.1	ND	0.8	26.0	0.06	5.0	0.0	5.0	0.09	0.05	0.65	0.03
200	0–15	5.3	0.1	ND	1.0	10.0	0.06	8.0	0.2	9.0	0.10	0.05	1.05	0.34
	15–30	6.0	0.1	ND	0.3	15.0	0.10	6.0	0.4	8.0	0.09	0.04	0.66	0.10
250	0–15	5.3	0.1	ND	1.0	10.0	0.06	8.0	0.2	9.0	0.10	0.05	1.05	0.34
	15–30	6.0	0.1	ND	0.3	15.0	0.10	6.0	0.4	8.0	0.09	0.04	0.65	0.10
300	0–15	5.7	0.1	ND	1.0	21.0	0.07	6.0	0.1	14.0	0.10	0.05	0.90	1.18
	15–30	5.8	0.1	ND	0.8	26.0	0.06	5.0	0.0	5.0	0.09	0.05	0.65	0.03
350	0–15	5.9	0.1	ND	0.7	10.0	0.09	5.0	0.5	27.0	0.09	0.06	0.80	0.22
	15–30	6.0	0.1	ND	0.4	21.0	0.05	5.0	0.7	18.0	0.10	0.04	0.50	0.83
400	0–15	5.7	0.1	ND	0.7	10.0	0.05	4.0	0.4	9.0	0.09	0.07	0.70	0.17
	15–30	5.8	0.1	ND	0.7	22.0	0.07	7.0	0.5	5.0	0.09	0.05	0.45	7.12
450	0–15	5.9	0.1	ND	0.9	16.0	0.09	6.0	0.7	27.0	0.07	0.06	0.95	0.47
	15–30	6.0	0.1	ND	0.7	45.0	0.07	8.0	0.5	20.0	0.08	0.05	0.60	0.08
500	0–15	5.6	0.1	ND	1.0	22.0	0.09	6.0	0.2	14.0	0.07	0.07	0.60	0.21
	15–30	5.6	0.1	ND	0.9	18.0	0.12	3.0	0.2	9.0	0.08	0.06	0.50	3.39

APPENDIX A(9) -

Physico-Chemical Characteristics of Soil Samples from Port Harcourt and Environs

Transect $PHSE_2T$	Depth (Cm)	Ph	Ec	THC (PPM)	Org.C. %	PO_4 (PPM)	TOTAL N %	NH_4^- (	NO_2^- PPM	NO_3^-)	Na^+ (	K^+ Meq/100g Soil	Ca^{2+}	Mg^{2+})
0	0-15	5.8	0.3	ND	1.1	10.0	0.07	7.0	3.1	46.0	0.12	0.15	0.80	0.61
	15-30	5.9	0.1	ND	0.8	15.0	0.11	7.0	3.8	5.0	0.11	0.20	0.95	0.46
50	0-15	5.5	0.2	ND	1.5	15.0	0.10	10.0	2.6	29.0	0.10	0.13	0.95	0.58
	15-30	5.7	0.1	ND	1.2	30.0	0.09	5.0	4.1	16.0	0.10	0.08	0.40	0.09
100	0-15	5.8	0.1	ND	0.9	24.0	0.12	6.0	2.9	14.0	0.08	0.09	1.60	1.63
	15-30	5.8	0.1	ND	0.8	33.0	0.13	7.0	4.8	27.0	0.08	0.09	0.90	2.10
150	0-15	5.5	0.2	ND	1.6	22.0	0.09	7.0	3.1	50.0	0.12	0.19	0.80	0.98
	15-30	5.7	0.1	ND	1.0	20.0	0.06	8.0	3.4	49.0	0.09	0.10	0.35	0.08
200	0-15	6.0	0.1	ND	1.2	23.0	0.12	8.0	2.8	18.0	0.08	0.10	1.55	1.80
	15-30	6.0	0.1	ND	0.9	13.0	0.12	6.0	4.7	19.0	0.08	0.06	1.00	0.86
250	0-15	6.0	0.1	ND	1.3	17.0	0.09	6.0	2.8	37.0	0.07	0.07	0.95	2.33
	15-30	6.1	0.1	ND	1.0	15.0	0.11	6.0	4.1	34.0	0.05	0.07	0.50	1.97
300	0-15	6.0	0.1	ND	1.6	16.0	0.19	7.0	3.0	49.0	0.08	0.21	1.30	1.80
	15-30	6.1	0.1	ND	1.4	24.0	0.14	6.0	3.4	24.0	0.07	0.19	0.85	1.06
350	0-15	6.1	0.1	ND	2.1	26.0	0.18	9.0	2.8	18.0	0.08	0.12	1.30	2.33
	15-30	6.3	0.1	ND	1.4	24.0	0.15	8.0	3.5	28.0	0.07	0.08	0.85	1.94
400	0-15	6.0	0.1	ND	1.2	20.0	0.12	8.0	3.1	50.0	0.12	0.20	0.80	1.60
	15-30	6.0	0.1	ND	1.0	22.0	0.12	7.0	3.4	46.0	0.08	0.12	0.65	2.00
450	0-15	6.1	0.2	ND	1.8	20.0	0.16	6.0	3.4	9.0	0.07	0.08	1.20	2.20
	15-30	6.1	0.1	ND	1.6	26.0	0.15	6.0	3.6	5.0	0.08	0.06	0.60	1.96
500	0-15	6.0	0.1	ND	0.9	34.0	0.12	6.0	2.9	13.2	0.07	0.09	1.69	1.60
	15-30	6.1	0.1	ND	0.7	33.0	0.13	7.0	6.6	27.3	0.08	0.08	1.08	2.23

APPENDIX A(10)

Physico-Chemical Characteristics of Soil Samples from Port Harcourt and Environs

Tansect PHNT	Depth (Cm)	Ph	Ec	THC (PPM)	Org.C. %	PO_4 (PPM)	TOTAL N %	NH_4^- (PPM)	NO_2^- (PPM)	NO_3^- (PPM)	Na^+ (Meq/100g Soil)	K^+ (Meq/100g Soil)	Ca^{2+} (Meq/100g Soil)	Mg^{2+} (Meq/100g Soil)
0	0-15	5.9	0.2	860	0.8	10.0	0.07	2.0	1.7	18.0	0.10	0.08	1.10	0.48
	15-30	6.0	0.1	720	0.7	8.0	0.10	3.0	0.8	32.0	0.09	0.07	0.65	0.23
50	0-15	6.0	0.1	340	1.0	10.0	0.09	6.0	3.1	9.0	0.12	0.06	1.25	0.37
	15-30	6.2	0.1	210	0.5	17.0	0.06	6.0	3.4	5.0	0.11	0.05	0.65	0.33
100	0-15	6.1	0.1	68	0.8	4.0	0.10	5.0	0.5	36.0	0.10	0.06	1.15	0.21
	15-30	6.1	0.1	44	0.6	11.0	0.07	4.0	0.5	11.0	0.08	0.05	0.65	0.03
150	0-15	5.8	0.2	18	0.7	26.0	0.11	6.0	4.1	14.0	0.10	0.08	0.85	0.42
	15-30	6.0	0.1	8	0.6	10.0	0.09	6.0	6.0	9.0	0.11	0.06	0.50	0.10
200	0-15	5.8	0.2	ND	0.7	26.0	0.11	6.0	4.1	14.0	0.10	0.08	0.85	0.42
	15-30	6.0	0.1	ND	0.6	10.0	0.09	6.0	6.0	9.0	0.11	0.06	0.50	0.10
250	0-15	6.0	0.2	ND	1.0	12.0	0.09	6.0	0.9	23.0	0.10	0.06	0.95	0.30
	15-30	6.0	0.1	ND	0.7	19.0	0.12	12.0	4.3	14.0	0.09	0.05	0.50	0.16
300	0-15	6.0	0.2	ND	1.0	12.0	0.09	6.0	0.9	23.0	0.10	0.06	0.95	0.30
	15-30	6.0	0.1	ND	0.7	19.0	0.12	12.0	4.3	14.0	0.09	0.05	0.50	0.16
350	0-15	5.8	0.2	ND	0.7	26.0	0.11	6.0	4.1	14.0	0.10	0.08	0.85	0.16
	15-30	6.0	0.1	ND	0.6	10.0	0.09	6.0	6.0	9.0	0.11	0.06	0.50	0.10
400	0-15	6.1	0.1	ND	0.8	4.0	0.10	5.0	0.5	36.0	0.10	0.06	1.15	0.21
	15-30	6.1	0.1	ND	0.6	11.0	0.07	4.0	0.5	11.0	0.08	0.05	0.65	0.03
450	0-15	6.0	0.1	ND	1.0	10.0	0.09	6.0	3.1	9.0	0.12	0.06	1.25	0.37
	15-30	6.2	0.1	ND	0.5	17.0	0.06	6.0	3.4	5.0	0.11	0.05	0.65	0.33
500	0-15	5.9	0.2	ND	0.8	10.0	0.07	2.0	1.7	18.0	0.10	0.08	1.10	0.48
	15-30	6.0	0.1	ND	0.7	8.0	0.10	3.0	0.8	32.0	0.09	0.07	0.65	0.23

APPENDIX B(1)

Microbiological Characteristics of Soil Samples from Port Harcourt and Environs

Transect $PHNW_1T$	Depth (Cm)	Bacteria Population ($X10^6$)	Fungi Colony Count ($X10^{-4}$)	Fungi Species Present %							
				As	Fm	Pm	Pe	Ra	Rs	Ta	Vr
0	0–15	20	10	90	5					5	
	15–30	22	4	88	12						
50	0–15	18	10	90	5					5	
	15–30	24	4	88	12						
100	0–15	18	19	38	10	30		14		8	
	15–30	20	13	84				16			
150	0–15	14	12		13	75		8		4	
	15–30	20	6		9	73		18			
200	0–15	16	12		13	75		8		4	
	15–30	24	6		9	73		18			
250	0–15	26	19	34	61			5			
	15–30	22	4	25	25	38		12			
300	0–15	18	19	38	10	30		14		8	
	15–30	22	13	84				16			
350	0–15	28	30	70		29				1	
	15–30	20	66			96		2	1	1	
400	0–15	18	12		13	75		8		4	
	15–30	22	6		9	73		18			
450	0–15	26	30	70		29				1	
	15–30	20	66			96		2	1	1	
500	0–15	24	19	34	61			5			
	15–30	22	4	25	25	38		12			

APPENDIX B(2)

Transect PHNW$_1$T	Depth (Cm)	Bacteria Population ($X10^6$)	Fungi Colony Count ($X10^{-4}$)	Fungi Species Present %							
				As	Fm	Pm	Pe	Ra	Rs	Ta	Vr
0	0-15	24	29	95				5			
	15-30	22	6	100							
50	0-15	38	3	100							
	15-30	26	46	93					7		
100	0-15	28	6	27		27		46			
	15-30	34	4	38		62					
150	0-15	28	10	95				5			
	15-30	24	3	100							
200	0-15	30	10	90				10			
	15-30	28	3	100							
250	0-15	36	16	78				20			2
	15-30	30	2	70				30			
300	0-15	34	18	75				25			
	15-30	26	4	75				25			
350	0-15	34	12	90				10			
	15-30	30	5	100							
400	0-15	28	6	27			27	46			
	15-30	32	4	38			62				
450	0-15	36	3	100							
	15-30	30	6	93					7		
500	0-15	26	29	95				5			
	15-30	24	6	100							

APPENDIX B(3)

Transect PHNE$_1$T	Depth (Cm)	Bacteria Population ($X10^6$)	Fungi Colony Count ($X10^{-4}$)	Fungi Species Present %							
				As	Fm	Pm	Pe	Ra	Rs	Ta	Vr
0	0-15	22	26	40		46		6	4	4	
	15-30	24	7	7		14			7	7	58
50	0-15	32	9		5	65		18		6	6
	15-30	24	9	11				17			72
100	0-15	24	18	23	20	31		6	3	17	
	15-30	22	13	80	12			4			4
150	0-15	34	8	20		33		47			
	15-30	28	5	44		22		22			12
200	0-15	26	29	44	16	20		13			7
	15-30	20	5	50		30		10			10
250	0-15	34	8	20		33		47			
	15-30	26	5	44		22		22			12
300	0-15	30	9		5	65		18		6	6
	15-30	24	9	11				17			72
350	0-15	28	29	44	16	20		13			7
	15-30	24	5	50		30		10			10
400	0-15	26	18	23	20	31		6	3	17	
	15-30	28	13	80	12			4			4
450	0-15	34	9		5	65		18		6	6
	15-30	26	9	11				17			72
500	0-15	30	26	10		50		6	4	4	
	15-30	26	7	7		14			7	7	58

APPENDIX 8(4)

Transect $PHNE_2T$	Depth (Cm)	Bacteria Population ($X10^6$)	Fungi Colony Count ($X10^{-4}$)	Fungi Species Present %							
				As	Fm	Pm	Pe	Ra	Rs	Ta	Vr
0	0-15	24	19	22	3	60		5			10
	15-30	26	58	5	1	92		2			
50	0-15	22	51	7	18	64		6	3	2	
	15-30	22	30		8	82		7		3	
100	0-15	20	16	39	10	32		13		3	3
	15-30	22	89	5		93		1			1
150	0-15	24	51	7	18	64		6	3	2	
	15-30	22	30		8	82		7		3	
200	0-15	24	40	11	8	70		5		5	1
	15-30	18	15	21		76				3	
250	0-15	28	28	20	13	55		7		4	1
	15-30	20	7	30	7	43		20			
300	0-15	26	16	39	10	32		13		3	3
	15-30	24	89	5		93		1			1
350	0-15	26	40	11	8	70		5		5	1
	15-30	20	15	21		76				3	
400	0-15	26	51	7	18	64		6	3	2	
	15-30	26	30		8	82		7		3	
450	0-15	28	28	20	13	55		7		4	1
	15-30	22	7	30	7	43		20			
500	0-15	26	19	22	3	60		5			10
	15-30	28	58	5	1	92		2			

APPENDIX 8(5)

Transect PHST	Depth (Cm)	Bacteria Population ($X10^6$)	Fungi Colony Count ($X10^{-4}$)	Fungi Species Present %							
				As	Fm	Pm	Pe	Ra	Rs	Ta	Vr
0	0-15	22	13	32	4	48		8		4	4
	15-30	18	10		11	58		26		5	
50	0-15	26	36	7	10	71		11		1	
	15-30	22	11	11	89						
100	0-15	38	25	18	8	58		10			6
	15-30	26	13		93			7			
150	0-15	20	30	16	16	60		8			
	15-30	18	27	12	85			3			
200	0-15	36	20	20	10	54		12			4
	15-30	22	15		90			10			
250	0-15	30	25	40	8	47		5			
	15-30	26	10	30	7	54		9			
300	0-15	24	30	16	16	60		8			
	15-30	18	27	12	81			7			
350	0-15	30	35	20	2	73		5			
	15-30	24	80	3	10	85		1			1
400	0-15	30	20	40	7	49		4			
	15-30	28	15	28	9	57		6			
450	0-15	28	50	6	10	80			4		
	15-30	26	40	3	7	86		2	2		
500	0-15	36	100	10	86				2	1	1
	15-30	46	40	7	6	84		3			

APPENDIX B(6)

Transect PHSW$_1$T	Depth (Cm)	Bacterie Population ($X10^6$)	Fungi Colony Count ($X10^{-4}$)	Fungi Species Present %							
				As	Fm	Pm	Pe	Ra	Rs	Ta	Vr
0	0-15	36	20	48		52					
	15-30	20	10	60		40					
50	0-15	36	25	45		55					
	15-30	18	10	68		32					
100	0-15	20	15	80		20					
	15-30	16	8	70		30					
150	0-15	22	6	80		20					
	15-30	20	10	70		30					
200	0-15	24	90	62		38					
	15-30	22	20	25		13			62		
250	0-15	28	60	62		38					
	15-30	22	20	25		13			62		
300	0-15	24	5	80		20					
	15-30	20	9	70		30					
350	0-15	24	70	98		1			1		
	15-30	16	10	55		9			36		
400	0-15	22	64	100							
	15-30	16	52	100							
450	0-15	24	68	100							
	15-30	20	60	94		6					
500	0-15	24	70	98		1			1		
	15-30	18	10	55		9			36		

APPENDIX B(7)

Transect PHSW$_2$T	Depth (Cm)	Bacteria Population (X10^6)	Fungi Colony Count (X10^{-4})	Fungi Species Present %							
				As	Fm	Pm	Pe	Ra	Rs	Ta	Vr
0	0-15		81	98		2					
	15-30		72	100							
50	0-15		53	99				1			
	15-30		69	99				1			
100	0-15		47	99						1	
	15-30		48	100							
150	0-15		55	100							
	15-30		40	100							
200	0-15		51	100							
	15-30		51	96	4						
250	0-15		47	99							
	15-30		48	100							
300	0-15		53	99				1			
	15-30		69	99				1			
350	0-15		51	100							
	15-30		51	96	4						
400	0-15		81	98		2					
	15-30		72	100							
450	0-15		60	99		1					
	15-30		64	100							
500	0-15		55	100							
	15-30		40	100							

APPENDIX B(8)

Transect PHSE$_1$T	Depth (Cm)	Bacteria Population ($X10^6$)	Fungi Colony Count ($X10^{-6}$)	Fungi Species Present %							
				As	Fm	Pm	Pe	Ra	Rs	Ta	Vr
0	0-15	38	8	69	31						
	15-30	34	31	82	5	13					
50	0-15	26	19	65		24			6	5	
	15-30	20	17	18	12	70					
100	0-15	26	40	99				1			
	15-30	32	7	14		79			7		
150	0-15	24	66	64		31		5			
	15-30	28	27	89		4			4	2	1
200	0-15	34	9	100							
	15-30	24	4			100					
250	0-15	32	9	100							
	15-30	26	4			100					
300	0-15	24	66	64		31		5			
	15-30	20	27	89		4			4	2	1
350	0-15	28	40	99				1			
	15-30	38	7	14		79			7		
400	0-15	26	19	65		24			6	5	
	15-30	24	17	18	12	70					
450	0-15	28	9	12	41	41				6	
	15-30	36	4	13	25	62					
500	0-15	36	8	69	31						
	15-30	30	31	82	5	13					

APPENDIX B(9)

Transect PHSE$_2$T	Depth (Cm)	Bacteria Population ($X10^6$)	Fungi Colony Count ($X10^{-4}$)	Fungi Species Present %							
				As	Fm	Pm	Pe	Ra	Rs	Ta	Vr
0	0-15	24	37	50	12	5					33
	15-30	26	28	47		25			2	13	13
50	0-15	28	14	82						7	11
	15-30	36	47	80	9					2	9
100	0-15	26	64	17	1	81			1		
	15-30	28	13	36		64					
150	0-15	24	54	79					20	1	
	15-30	30	62	42		41					17
200	0-15	26	14	82						7	11
	15-30	30	47	80	9					2	9
250	0-15	28	64	17	1	81			1		
	15-30	30	13	36		64					
300	0-15	26	54	79					20	1	
	15-30	30	62	42		41					17
350	0-15	24	27	58		30			8	4	
	15-30	26	18	22	14	64					
400	0-15	20	37	50	12	5					33
	15-30	24	28	47		25			2	13	13
450	0-15	22	28	23	21	56					
	15-30	26	63	13	2		85				
500	0-15	26	27	58		30			8	4	
	15-30	28	18	22	14	64					

APPENDIX 8(10)

Transect PHNT	Depth (Cm)	Bacteria Population ($X10^6$)	Fungi Colony Count ($X10^{-4}$)	Fungi Species Present %							
				As	Fm	Pm	Pe	Ra	Rs	Ta	Vr
0	0-15	26	6	8	58	26		8			
	15-30	36	2	34	33					33	
50	0-15	30	3	90		3			4	3	
	15-30	28	8	27	27	40				6	
100	0-15	26	26	80					20		
	15-30	20	11	64		32					4
150	0-15	28	18	77	6	11		6			
	15-30	36	8	100							
200	0-15	26	18	77	6	11		6			
	15-30	32	8	100							
250	0-15	40	43			100					
	15-30	36	7	54	15				15	16	
300	0-15	42	43			100					
	15-30	32	7	54	15				15	16	
350	0-15	36	18	77	6	11		6			
	15-30	28	8	100							
400	0-15	26	26	80					20		
	15-30	20	11	64		32					4
450	0-15	38	3	90		3			4	3	
	15-30	34	8	27	27	40				6	
500	0-15	24	6	8	58	26		8			
	15-30	36	2	34	33					33	

APPENDIX C(1) Checklist of Vegetation Within the Port Harcourt and Environs Field/Transects

SPECIES		PHNT/ PHST	PHNW$_1$T/ PHSW$_1$T	PHNW$_2$T/ PHSW$_2$T	PHNE$_1$T/ PHSE$_1$T	PHNE$_2$T/ PHSE$_2$T	TOTAL	MEAN
Acion	bateri			40			40	8
Albizzia	labella	60	230		10	10	310	62
Albizzia	zygia	5			20		20	4
Albizzia	adentifelia	50	20	120	40		230	46
Albizzia	Spp.			220			220	44
Akornea	cordifetia	150	400	970	300	360	2180	436
Ancephalantus	Sp.				100		100	20
Alstonia	congensis							
Amphimas	Sp.							
Anacaedium	occidentialis			40			40	8
Anthiasis	africane				60		60	12
Anthocleista	dialonensis	30					30	6
Anthonata	Sp.	100	360	200			660	132
Banana			100		340	380	820	164
Baphia	nitida		330	320	200	170	1020	204
Bestinio	Sp.		10	160			170	34
Bombosa	vulgavis	50		60			110	22
Carica	papaya	30		40			70	14
Chlorephora	excelsa			40	180		220	44
Ceiba	pentendra	30		100	60	20	210	42
Citrus	Sp.			40			40	8
Cleistopholis	peteus							
Cocos	nucifera		10				10	2
Cola	acuminata		10				10	2

APPENDIX C(2) Vegetation in the Port Harcourt and Environs Field/Transect (Contd.)

SPECIES		PHNT/ PHST	PHNW$_1$T/ PHSW$_1$T	PHNW$_2$T/ PHSW$_2$T	PHNE$_1$T/ PHSE$_1$T	PHNE$_2$T/ PHNE$_2$T	TOTAL	MEAN.
Combretum	hispida							
Combretum	giganthia				20		20	4
Combretum	pennicutata			180		20	200	40
Combretum	Sp.	30		160			190	38
Comelina	Spp.			320		70	390	78
Costos	alfa			640			640	128
Dalbergia	Sp.		90				90	18
Danmeli	Sp.							
Dialum	guinnensa							
Draecinia	manii	170	120	380	320		990	198
Dracryodes	edulis	90	150	60	200	20	520	104
Draecunia	guinnensa				100	20	120	24
Draecunia	Sp.			160			160	32
Elaeis	guinnensis	400	310	380	360	620	2070	414
Emilia	Sp.	1200	350	240	360.	540	2790	558
Emilia	Sonchisocia					160	160	32
Fagara	Spp.	60	130				190	38
Ese						40	40	8
Ficus	exaspirata	230	240	290	270	280	1080	216
F.	ingeus		60	10			70	14
F.	escucenta		40	50	60		150	30
Funtumia	elastica	110					110	22

APPENDIX C(3)

SPECIES		PHNT/ PHST	$PHNW_1T$/ $PHSW_1T$	$PHNW_2T$/ $PHSW_2T$	$PHNE_1T$/ $PHSE_1T$	$PHNE_2T$/ $PHSE_2T$	TOTAL	MEAN
Gnestis	feruginea	150	200	110	20	320	800	160
Holarrhena	floriburda	50	10			40	100	20
Honca	hleniana							
Harungana	Sp.	320	10				330	66
Harungana	madagascariensis	100				60	160	32
Havea	braziliensis					40	40	8
Khaya	grandifolia					40	40	8
Irvingia	Sp.	30					30	6
I.	sabonensis							
I.	Smittii	30					30	6
Khaya	grandifolia							
Ladophia	Owerriensis	50					50	10
Lannea	Sp.							
Lecaniodiscus	Sp.	160			120		280	56
L.	cupanicides				60		60	12
Lenchocarpus	Sp.	30	300		70	20	420	84
Lophira	etata	50					50	10
Masebotryia	Sp.							
Malletua	Sp.	450	400	640	960	640	3090	618
Manihot	utilisima	150	50	170	240	180	790	158
Mangifera	indica		60	20			80	16

APPENDIX C(4) Table 7: Contd.

SPECIES		PHNT/ PHST	PHNW_1T/ PHSW_1T	PHNW_2T/ PHSW_2T	PHNE_1T/ PHSE_1T	PHNE_2T/ PHSE_2T	TOTAL	MEAN
Mausonia	Sp.							
Maranthoclea	Sp.							
Mitracyna	ciliate					640	640	128
Musa	sapientum	350		120	200	160	480	96
Musanga	cercropiodes	30					30	6
Nauclea	esculenta	150	50		60	260	420	84
Napoleona	vogeli	150	210	40	20	800	1220	244
Newbouldia	veavis		90	60	180	40	370	74
Olax	Sp.							
Pacry			70	20			90	18
Paligota	hisuta	650	550	180	280	640	2250	450
Pentaclithra	macrophylia							
Pistadeniastrum	africanum							
Psidium	guojava	300	270	180	520		1270	254
Pterocarpus	Sp.	50			20		70	14
P. —	Soyauxii							
Rauovophia	vomitoria	10			60		70	14
Rycanthus	augolense	120	20	60		80	280	56
R.Landolyhia	Owweariensis		10			160	170	34
Raphia	hookeri	310				160	470	94

APPENDIX C (5)

SPECIES	PHNT/ PHST	$PHNW_1T$/ $PHSW_1T$	$PHNW_2T$/ $PHSW_2T$	$PHNE_1T$/ $PHSE_1T$	$PHNE_2T$/ $PHNE_2T$	TOTAL	MEAN.
Rhyzophora Sp.	50					50	10
Sida acota	320		120	480		920	184
Solamum Spp.		10				10	2
Spondia mombin	50	60	80	80	240	510	102
Sterculia tragacautha		20		40	60	120	24
Talinum triangulare				120		120	24
Terminalia Ivorensis					80	80	16
Urena lobata	150	250	350	540	700	1990	398

APPENDIX D: Checklist of Phytoplankton Species in Port Harcourt and Environs Sampled Streams

Specie		Abundance Stream A	B	C
BACCILARIOPHYCEAE (DIATOMS)				
Melosira	granulata	4	7	30
M.	Varcuis	-	13	15
Navicula	muralis	-	9	15
Nitzchia	acicularis	4	8	9
Synedra	acus	1	2	8
S.	ulna	2	5	19
CYANOPHYCEAE				
Chrococcus	limnetica	5	14	24
Microcystis	aeruginasa	10	7	14
Oscillatioria	limnetica	4	6	9
O.	limosa	6	8	12
CHLOROPHYCEAE				
Ankistrodesmus	falcatus	-	13	75
A.	spiralis	-	19	85
Cosmarium	bioculatum	26	70	130
Micrasteruim	crux	1	2	20
Scenedesmus	quadricaudo	6	9	20
S.	obliquus	2	5	19
Stranrodesmus	connatus	2	6	10
S.	triangulata	-	2	5
DINOPHYCEAE				
Dinobryon	cormita	2	2	11
Peridinium	acciculifornes	1	8	6
P.	anctum	-	5	8
Ceratuim	cornutum	4	14	13

APPENDIX E: Checklist of Zooplankton Species Within the Sampled Streams

SPECIE		DENSITY		
	STREAM	A	B	C
ROTIFERA				
Anuraeopsis	naricula	1	1	1
Ascomorpha	eucaudis	–	–	2
Asplanchna	brightwelli	1	3	5
Brachionus	angulanis	1	4	10
B.	calyciflorus	–	2	7
B.	caudatus	–	3	5
Conochilus	hippocrepis	–	1	3
Filinia	opoliensis	–	2	2
Lecane	decipens	–	–	1
Mytilina	ventralis	–	–	1
CLADOCERA				
Alona	Sp.	–	2	5
Ceriodaphnia	Cornuta	1	1	3
Diaphanosoma	excisum	–	2	1
Macrothrix	Spinosa	1	3	7
COPEPODA				
Mesocyclop	Sp.	–	–	3
Thermocyclops	Crassussi	–	–	1

APPENDIX F: Physico-Chemical Characteristics of Sediment Within the Sampled Streams

Sediment Characteristics	(Stream) Sediment		
	A	B	C
Sampling Time	AM	AM	AM
Temperature ^{o}C	20.00	19.37	17.40
Alkalinity	16.71	13.45	18.53
PH	6.40	6.60	6.30
Conductivity	230.00	216.00	238.00
Depth	10.00	10.00	15.00
Colour	Brown	Brown	Brown
THC	21.8	21.31	26.43
Na	15.26	14.34	15.72
K	4.98	5.01	5.63
Mg	2.46	2.57	2.26
PO_4-P	3.86	3.02	3.13
NO_3-N	410	370	420
NH_4	3.20	2.20	2.50
NO_2	2.60	2.60	2.60
Cl	11.20	11.53	11.78
SO_4	214.00	119.00	203.00

APPENDIX G: Apparent Resistivity Readings For The Three Borehole Locations In Port Harcourt and Environs

AB/2 (m)	MN (m)	P.H.and Environs BH1 Pa (nm)	P.H.and Environs BH2 Pa (nm)	P.H. and Environs BH3 Pa (nm)
2	1	185.6	236.8	3246.1
3	1	142.3	95.4	2900.6
4	1	150.6	79.7	2600.8
9	1	159.3	110.0	2050.9
9	1	190.7	151.2	1506.3
9	4	210.3	132.7	1006.7
15	4	320.6	246.9	550.4
25	4	850.1	493.5	364.7
40	4	1206.9	1106.1	900.1
50	4	1600.0	1052.7	1125.7
75	4	2000.1	1145.6	1732.5
75	20	1816.4	1238.9	1920.3
100	20	1925.8	1003.4	1800.0
150	20	1506.9	1000.1	1403.6
200	20	1389.1	750.6	1216.3
300	20	950.6	566.2	1099.8
300	40	1100.8	649.5	950.3
400	40	856.7	546.7	865.9
500	40	7001.3	425.0	725.4

Appendix H: Geochemical and Physical Characteristics of the Sampled Boreholes

Geophysico-Chemical Characteristics	Borehole		
	BH1	BH2	BH3
1. Temperature	26.30	26.00	26.20
2. PH	6.70	7.00	6.90
3. Electrical Conductivity	16.50	15.80	16.50
4. Turbidity	1.00	1.00	1.00
5. Cl^-	6.80	6.50	7.00
6. Na^+	4.40	5.00	5.10
7. K^+	3.50	3.90	4.20
8. Mg^{2+}	1.40	1.50	1.60
9. Ca^{2+}	2.60	3.00	3.30
10. Total Alkalinity	48.00	60.00	55.00
11. Total Organic Carbon	5.60	2.50	2.60
12. Mn	0.30	0.20	0.16
13. Fe	0.04	0.04	0.04
14. Cd	ND	ND	ND
15. Cr	0.01	0.01	0.01
16. Pb	ND	ND	ND
17. Cu	0.05	0.07	0.06
18. Ni	ND	ND	ND
19. V	ND	ND	ND
20. Hg	ND	ND	ND
21. Zn	18.00	20.00	21.00
22. Ni/V ratio	ND	ND	ND
23. Hardness (Ca)	6.20	4.30	4.50
24. Total Hardness	9.30	8.00	7.80
25. Suspended Solids	98.00	90.00	92.00
26. Total Hydrocarbon Concentation (ppm)	3.00	1.30	1.00

Department of Geography,
University of Nigeria,
Nsukka.

February, 1994.

Dear Respondents,

QUESTIONNAIRE

As part of the requirement for the award of the degree of Master of Science (M.Sc.) in Environmental Management, I am carrying out a research project on the:

"ASSESSMENT OF ENVIRONMENTAL IMPACT OF PETROLEUM ACTIVITIES IN PORT HARCOURT AND ENVIRONS."

I will be very grateful if you would accurately respond to the questionnaire items below by ticking the appropriate space or by writing in the answers.

Any information you offer shall be treated with strict confidence and your anonymity is highly guaranteed.

Thank you.

Yours sincerely,

Olemefom Prince N.

PART A: IDENTIFICATION/HOUSEHOLD INFORMATION COLUMN

1. State of Origin: _____
2. Local Government Area: _____
3. Community/Town: _____
4. Village/Ward: _____
5. Sex: Male ☐ Female ☐ 6. Age: ☐☐
7. Marital Status: Married ☐ Single ☐
8. Family/Household Size: ☐☐
9. Highest Educational Status: _____
10. Occupation: (i.e) Your occupation and/or your parents':
    (a) Farming ☐ (b) Business/Trading ☐
    (c) Civil Servant: ☐ (d) Fishing ☐
    (e) Unemployed: ☐ (f) Student: ☐
11. Place of Work/Residence:
    (a) at home ☐ (b) inside village ☐
    (c) outside village ☐

PART B.: AVAILABILITY OF BASIC AMENITIES

12. Which of the following amenities does your community have? (a) Pipe-borne water ☐ (b) Electricity ☐

(c) Hospital/Health Centre ☐

(d) Motorable road (tared ☐

(e) Primary School ☐ (f) Secondary School ☐

(g) Post Secondary School ☐ (h) Others ☐

13. Where available, who provided the follow amenities? (Government, Community, Oil Company, individual)

(a) Pipe-borne water _____

(b) Electricity: _____ _____

(c) Hospital/Health Centre: _____

(d) Tared roads: _____ (e) Primary Schools _____ (f) Secondary _____

(g) Post-secondary _____ (h) Any Other _____

14. (Rank in order of priority). List 3 most disturbing problems of your community: Who should do something about it?

	Problems		*Responsibility*
(a)	_____	(a)	_____
(b)	_____	(b)	_____
(c)	_____	(c)	_____

PART C.: ECONOMIC AND SOCIAL INFORMATION COLUMN

15. Name the Oil Company or companies operating in your community (Only those producing oil).

(a) _____ (b) _____

(c) _____ (d) _____

16. Has there been any oil spillage(s) since they began operation? Yes ☐ No ☐

17. Has your community suffered any adversity from oil spills or gas flares? Yes ☐ No ☐

18. Which resource(s) of your community are often affected during these incidences?

(a) Land ☐ (b) Stream/creek ☐

(c) Farm lands ☐ (d) Other ☐

19. Specify clearly: How are the above resources affected?

(a) Land _____ (b) Water _____ (c) Farmlands _____

20. Has the provision of public utilities by oil companies stopped the adverse effects of oil spills or gas flares in your community? Yes ☐ No ☐

21. Which economic activity does your community mainly depend on? (e.g) Farming, Fishing etc. _____

22. Is the above activity the same as your family's?
Yes ☐ No ☐

23. Is your community's or family's farmlands or fishing centres close to oil producing field/location?
Yes ☐ No ☐

24. Has there been any incidence(s) of gas flaring or oil spills wastes discharged in or near your farmlands/fishing areas? Yes ☐ No ☐

25. If yes, how often does this occur? (a) daily ☐
(b) weekly ☐ (c) monthly ☐ (d) Yearly ☐

26. If there are no gas flaring in your community, please specify: _____

27. Which of the following crops or vegetation does the oil or gas falres wastes affect? Any effects on their quality/quantity:

	Lowered Quantity	Reduced quality
(a) Yam	☐	☐
(b) Cocoyam	☐	☐
(c) Cassava	☐	☐
(d) Oil Palm	☐	☐
(e) Vegetables	☐	☐
(f) Plantain/ Banana	☐	☐
(g) Rice	☐	☐

28. Has the problem above negatively affected your family's income from the crops? Yes ☐ No ☐

29. Has the income from your crops steadily decreased since the past 10 years or more? Yes ☐ No ☐

30. If yes, kindly provide the following information in rough estimates (VALUE IN ₦)

INCOME FROM	1984	1985	1986	1987	1988	1988	1990	1991	1992	1993
a) Yam										
b) Coco-yam										
c) Cassava										

INCOME FROM	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
d) Oil Palm										
e) Vege-tables										
f) Plantain/ Banana										
g) Rice										

31. How has the quantity/quality of the crops above decreased over the years? (Write value or estimates in kg.)

Yield in (kg)	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
a) Yam										
b) Coco-yam										
c) Cassava										
d) Oil Palm										
e) Vege-tables										
f) Plantain/ Banana										
g) Rice										

32. Has your family or community abandoned any farmlands resulting from the above incidences? Yes ☐ No ☐

33. Are there any oil producing wells near or within your water courses Yes ☐ No ☐

34. Have they ever disrupted your fishing activities? Yes ☐ No ☐

35. Have you or your community sustained any financial losses resulting from the disruptions? Yes ☐ No ☐

36. What is the major cause of the disruption? _____ _____ Has it affected the quantity of fish you catch from your water courses over the years? Yes ☐ No ☐

37. If yes, provide the following information in rough estimates

FISH CATCH	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
QUANTITY (Kg)										
VALUE IN ₦										

38. Has your family or community ever been forced to relocate as a result of an oil spill incidence? Yes ☐ No ☐

39. Was the relocation permanent or temporary? _____