

**ASSESSMENT OF POST-SPILL IMPACT ON SOIL, CASE
STUDY (K.DERE) OGONI LAND**

BY

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CERTIFICATION

We certify that this work "**ASSESSMENT OF POST-SPILL ON THE SOILS OF BOMU COMMUNITY IN (K.DERE) OGONI LAND IMPACTED BY OILSPILL**" was carried out by **ODOCHA BOMA KELECHI NJIDEKA (REG NO: 20085633448)** in partial fulfillment for the award of the degree of Masters of Science (M.Sc.) in Environmental Technology (Pollution Control) Option in the Department of Environmental Technology of the Federal University of Technology, Owerri.

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DEDICATION

This work is dedicated to God Almighty for giving me the perseverance, financial favour and making my dream come true.

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ABSTRACT

The supply of food, water, and agricultural resources is fast becoming a difficult issue. This is because the resources are heavily polluted as a result of intensive crude oil spill, and oil related activities in the state. This study focused on the assessment of soil samples from Ogoni, (k- Dere) community. To ascertain the level of pollution that may have occurred. Different parameters were analyzed, namely pH, total petroleum hydrocarbons, nitrate, phosphate, sulphate, zinc, iron, magnesium, copper, cobalt, chromium, nickel, lead, cadmium, calcium. Analyses used were Gas chromatography, Ultra Violet Visible Spectrophotometry and Atomic Absorption also Environmental Guidelines and Standard for the Petroleum industry in Nigeria (EGASPIN). The intervention between the physical variables was explored using the Pearson Product Moment Correlation Coefficient®. The one way ANOVA was used to determine variance of equality in spatial means of the variables. The result showed that TPH correlated positively with phosphate, nickel, zinc and copper. The physiochemical variables did not vary significantly across sample location. [$F_{(2.01)} < F_{crit (3.95)}$]. While few parameters exceeded standards, while other parameters fell within acceptable limits. This result shows that soils in ogoni k-dere community is not totally fit for agricultural activities, most especially for people living within that community. Adequate control measures were recommended to control the assessments of the post spill of crude oil in that community and so many other communities not mentioned for sustainability.

CHAPTER ONE: INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Crude oil has had profound impact on the world civilization than any single natural resource in recorded history. Nigeria joined the league of oil producing nations on August 3rd, 1956 when oil was discovered in commercial quantities and today ranks as the leading oil and gas producer in Africa and the 6th largest oil exporter in the world. Impacts of Oil spills along the Nigerian coast (The Association for Environmental Health and Sciences).

Nigeria is also Africa's most populous nation with 140 million peoples as announced for the recently conducted National Census in 2006. As oil was struck in commercial quantities in Nigeria, it also signaled the beginning of a profound transformation of Nigeria's political and economic landscape. Since the 1970s, oil has accounted for about 80% of the Nigerian government's revenue and 95% of the country's export earnings. Interestingly, all of Nigeria's oil and gas resources come from its Niger delta region occupied by a mosaic of indigenous nationalities. The Niger delta sustains the largest wetland in Africa and one of the largest wetlands in the world. It consists of a total landmass of approximately 70,000 square kilometers with the third largest mangrove forest in the world, a most extensive fresh water swamp, coastal ridges, fertile dry land forest and tropical rainforest characterized by great biological diversity. Seasonal flooding and sediment deposits over thousands of years have made the land fertile. The immeasurable creeks and streams have in the past, provided habitat for an

abundance of fish and marine wildlife. Today the Niger delta is home to approximately 20 million people grouped into several distinct and ethnic groups, amongst which is the Ogoni. According to Environmental and Socio-Economic Characteristics (Lagos: Niger Delta Environmental Survey, September 1997), over 6000 spills has been recorded in the 40 years of oil exploitation in Nigeria, with an average of 150 spills per annum in the period of 1976 – 1996. 647 incidents occurred resulting in spillage of 2,389407.04 barrels of crude oil with only 549,060. 38 barrels recovered and 1,820,410.50 barrels of oil were lost to the eco-system. Source of oil spillage results from, Natural seeps of crude oil from the sea bed through fissures in rocks, off-shore oil seeps, from drilling and oil exploration, Air-born oil droplets, from unburnt fuel and Combustion engines on land, and discharge from shipping & loading of oil tankers, petroleum product storage tanks, in fuel dumps, refineries and filling stations, Pipe lines carrying petroleum Products. Causes of this spillage could be as a result of burial of tanks and pipe for a very long time and corrosion and rusting begin to take their roll, bunkering activities at sea, and land frustrated citizens of community can break the pipeline, accidental truck spills, Intentional discharge on the sea, to relief a slip and save life, as a weapon of sinking in adversary, slip military training, aviation fuel.

The spills lead to adverse environmental effects on soil forest, resulting to deforestation and desertification, including water bodies pollution in host communities in some cases affected communities are forced to emigrate to other communities in search of

livelihood. Most of the socio economic impact of oil pollution identified includes farm land degradation as a major problem, deforestation and desertification.

1.2 STATEMENT OF PROBLEM

A post-spill, which occurred in 2009 by one of our multinational organization, carried out a cleanup exercise and subsequent remediation. But that incidence leads to the notice of loss of agricultural production, deforestation and caused migration, in search for food.

Therefore the preliminary examination of this study is to carry out a research to determine if the cleanup and remediation exercise was carried out. And if remediation was done, Could there still be traces of potential hazard on the soil?

1.3 AIM AND OBJECTIVES

The aim of this research is to ascertain the efficiency of remediation of soil from oil spill, using relevant physiochemical indicators. To achieve this aim, the following objectives become necessary.

- Determination of physiochemical characteristics of soils in impacted areas.
- Determining the trace metal concentration in impacted soils.
- Determination of the Hydro-carbon content of soil of impacted area.
- Comparative analysis of physiochemical variables with regulatory standards as to ascertain compliance.

- The inter-relationship between the physiochemical variables in impacted soil.

1.4 SCOPE AND LIMITATION OF STUDY

The current research will be carried out in the K.DERE Community which is mainly affected by the activities of oil production in Ogoni.

- Ecological indicators used in these works are of the physiochemical category only.
- The numbers of trace metals to be analyzed are iron, magnesium, cadmium, zinc, copper, chromium, nickel, cobalt, calcium, lead. And is limited to this number due to financial constraint.

1.5 JUSTIFICATION OF STUDY

This study is carried out to have an authentic knowledge of treatment of spills associated with traces of environmental problems such as soil degradation, resource degradation, pollution, poverty and misery etc. Also to find out if there are negative impacts on the physiochemical properties (temperature, structure, nutrient status, & pH) of the soil.

CHAPTER TWO: LITERATURE REVIEW

2.1 THE PETROLEUM INDUSTRY AND OIL POLLUTION

Any addition to air, water, soil, or food that threatens the health survival, or activities of humans or other living organism is called pollution (Miller, 1996). Thus, the particular chemical or form of energy that causes such harm is called a pollutant. Various countries of the world involved in petroleum production and processing often experience frequent oil spills which are often caused by blowouts, tanker accidents, including accidental and international rupture of oil pipeline leading to the introduction of crude oil and refined petroleum products into the terrestrial and aquatic environment (Ari, 1996). Crude oil or petroleum is a gooey liquid consisting mostly of hydrocarbon compounds with small amounts of oxygen, sulfur, and nitrogen compounds (Miller, 1996).

It therefore cannot be overemphasized that most of the environmental disaster in our country are due to oil spills which occur despite stringent measure put in place to prevent them (Ari 1998). Oil spill of any nature can have devastating effects on the flora as well as the health of the inhabitants of the area (Essien, 1998).

According to Ozumba (1999), Nigerian has experienced a number of calamities from oil well blowouts and oil pollution. Example of such disasters are blowouts and pipeline leakage from shell BP Bomu ii blow- out of 1970; the ELF obagi-blowout and the Texaco funiwa – 5blowout of 1980, and the Agip – Oyakama pipeline leakage of 1980.

These incidents had disastrous effects on land fresh water, swamp, marine life, disrupting general ecology of the affected area. Ozumba reported that from 1993 – 1997, a total of 406 spills occurred spilling almost 15790.8 bbls of oil, out of which sabotage is said to account for only 17% of incident and 78% of the total where spilled. Ozumba further pointed out that numerically, more oil spills (over 60%) are due to operations related cases, but in terms of volume of oil spilled sabotage account for more than 80%. Essien (1998) reported that environmental pollutions is seen as an unfavorable alteration of human surroundings through direct or indirect effect on chemical, physical and biological characteristics of the air, land, and water, influenced primarily by man's activities on the environment. Ozumba went further to say that oil spillage is the discharge of any kind of oil including petroleum, fuel oil, grease, oil refuse or crude, and oil mixture with water other than drilling oil into the environment. According to Ari (1998), our area is greatly affected and we are faced with degradation and deforestation.

2.2 DESCRIPTION OF THE SOIL

The term soil has different meaning to individuals depending on their scientific background and experience. Soil to an Agronomist or Botanist is best defined as a medium for plant growth. An Engineer refers soil to the loose material that lies between the ground surface and solid rock. Soil scientist defined soil as the unconsolidated

mineral and organic matter at the earth's surface that has been altered by soil formation processes (plerzynski et al, 2005). Although, there is no uniform or comprehensive definition of soul, it is apparent that the functions of soil are numerous. Soil is a dynamic ecosystem that supports plant life by providing essential requirements for plant growth and support.

Soil is also necessary to support and sustain human life because it provides natural resources, support dwelling and roads. It is a means of recycling waste materials that are produced daily. Soil itself is very complex because it provides vascular plant with a medium for growth and supply micro-organisms with most of their nutritional requirements.

Further, the nutrient status of ecosystem does not only limit plant growth, but also the productivity of consumer type organisms further down the food chain (Pidwirny, M, 2006).

2.3 COMPONENTS OF SOIL

Soil is a complex assemblage of clay, humus, minerals, detrial materials (quartz), water, organic compound, trapped gases and living organisms. The average consumption of earth's crust with respect to major components is weight percent;

TABLE 2.1: MAJOR COMPONENTS OF SOIL PER WEIGHT PERCENT

Components	Percentage
Oxygen	46.6
Silicon	27.7
Aluminum	8.3
Iron	5.0
Calcium	3.63
Sodium	2.53
Magnesium	2.53
Potassium	2.59

Source Pidwirny, Michael (2006)

During weathering process, the “feldspars” and other silicate minerals are broken up by natural substances like water, sunlight, heat, releasing chemical compounds which include bases, silica, oxides of iron ($Fe_2 O_3$) and Al_2O_3 (Aluminum). The type of soil and its characteristics in an area makes a key contribution to the landscape and the agro-ecosystem.

2.4 SOIL PROFILE MODEL

Most soil has a distinct profile or sequence of horizontal layer. Generally, these horizons result from the processes of chemical weathering, eluviation, illuviation and organic decomposition. Five layers can be represented in a typical soil profile as horizon O, A, B, C, and R.

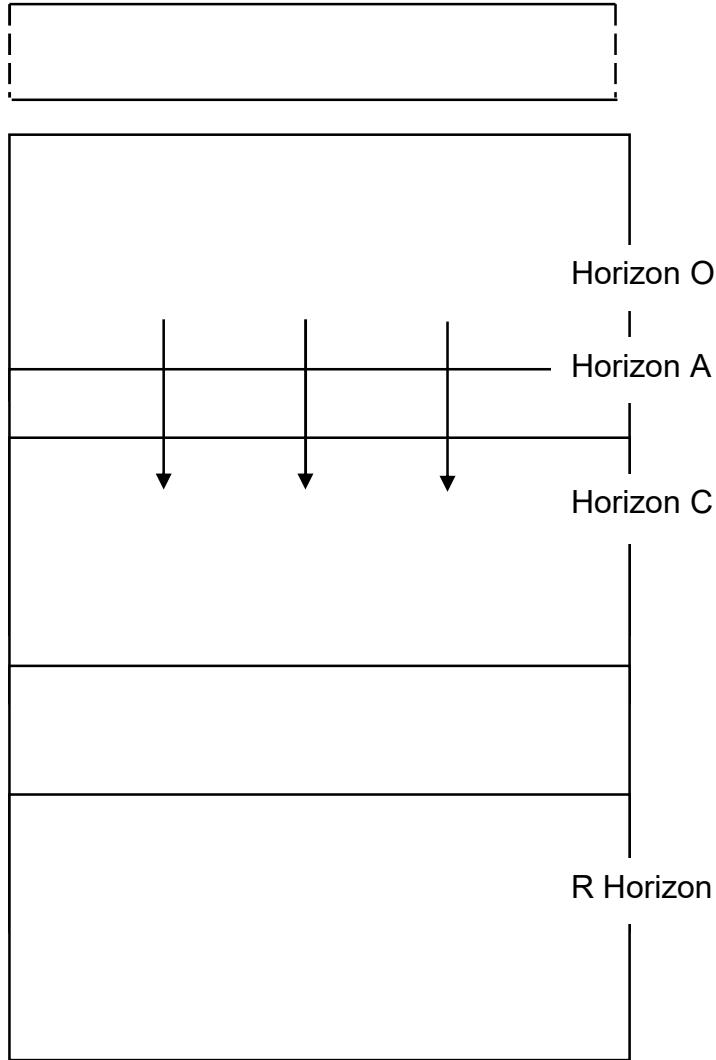


FIGURE 2.1 Typical Layer found in Soil Profile

Source Pidwirny, Michael (2006)

The O horizon is the topmost layer of most soils. It is composed mainly of plants litter at various levels of decomposition and humus. A horizon is found below the O layer, the layer is composed of mineral particles which have two characteristics. It is the layer in which humus and organic material are mixed with mineral particles. It is a zone of translocation (downward movements of water in the soil) from which eluviations have removed finer particles and soluble substances, both of which may deposit at the lower

layer. Thus horizon A is dark in colour and usually light in texture and porous. The horizon is commonly differentiated into a dark upper horizon or organic accumulation. Horizon B is a mineral soil layer which is strongly influenced by illuviation. Consequently, this layer receives materials eluviated from the A horizon. The B horizon also has a higher bulk density than A horizon due to its enrichment of clay particles. Horizon B may be coloured by oxides of iron and aluminum or calcium carbonate illuviated from A horizon

Horizon C is composed of weathered parent material. The texture of this material can be quite variable with particles ranging in size from clay to boulders. Horizon C has also not been significantly Influenced by the pedogenic processes, translocation and organic modification. The final layer in a typical soil profile is the R horizon. The layer simply consists of unweathered bedrock. Riser, J.A. and D.E. Baker (1990).

2.5 PROPERTIES OF SOIL

2.5.1 Physical Properties of Soil

Environmental quality is influenced to a large degree by its moisture content, particle size, specific gravity, bulk density, dry density, permeability and porosity. Functions of soils can be determined within the landscape by their ability to allow water and gas movements. The movement of water and gas in the soil is influenced by its texture, slope direction, and landscape position. Riser, J.A. and D.E. Baker (1990).

2.5.2 Moisture Content: Soil moisture content is referred to as the water content which is an indicator of the amount of water present in the soil. By definition, moisture content is the ratio of the weight for water in a sample to the weight of solids in the sample, expressed as the percentage (%)

Mathematically, moisture content, w

$$w = \frac{W_w}{W_s} \times 100$$

Where,

W = moisture content of the soil

W_w = Weight of Water in the sample, that is initial weight of the moist soil-weight of oven dried sample

W_s = weight of soil solid in the sample oven dried weight of the soil.

W_s and w_w may be expressed in any unit of weight but must be the same unit.

2.5.3 Particle Size: Soils are composed of solid materials ranging in size from stones to fine clays. The layer material called coarse or mineral fragments including stones, cobbles and gravels are physically and chemically weathered over a long period of time to form smaller soil particles of sand, silt, and clay. Soil particles are defined on the basis of their diameter, although these particles rarely exist as spherical objects. Soil particles size often differs between classification schemes used by different groups. U.D

Department of Agriculture System, soil survey staff, (1999; 2004)

TABLE 2.2 PARTICLE SIZE MODEL

Types of Minerals	Size Range
Sand	2.0-0.06mm
Silt	0.06-0.002mm
Clay	Less than 0.002mm

Source Pidwirny, Michael (2006)

Clay is probably the most important type of mineral particles found in a soil. Despite their small size, clay particles have a very large surface area relative to their volume. Large surface area of clay is highly reactive and has the ability to attract and hold positively charged nutrient ions. These nutrients are available to plants roots for nutrition. Clay particles are also flexible and plastic because of their lattice-like design which allows clay particles to absorb water and other substances into their structure.

2.5.4 Specific Gravity: The term is defined as the ratio of the weight of a given volume of water. It explains how heavier or lighter the materials than the water. Alternatively, specific gravity of soil is defined as the ratio of the unit weight of solids in the soil to the unit weight of water.

Mathematically, specific gravity;

$$G_s = \frac{W_s/V_s}{Y_w}$$

$$G_s = \frac{W_s}{V_s Y_w}$$

Where,

G_s = Specific gravity of soil

W_s = Weight of soil (lb or g)

V_s = Volume of solids (cm^3 or ft^3)

Y_w = Unit weight of water (Ig/cm^3)

2.5.5 Bulk Density: Is defined as the mass of a unit volume of dry soil which also reflects the total pore space of a soil. The pore size or porosity of soil together with bulk density of soil determined its structure. Sand soil has single grained structure because of the general uniformity in particle size. The test can provide a gross measure of particle size and dispersion which can affect flow of material consistency and reflect packaging quantity (ASTM 1895B). Bulk density is not an intrinsic property of a materials; it can change depending on how the material is handled. It also depends greatly on the materials and degree of compaction. Bulk density is calculated on an oven dry weight basis and does not take into consideration the amount of water present in the soil at the time of sampling. Boele, R., Fabig, H., Wheeler, D. (2001)

2.5.6 Permeability: This is referred to as the propensity of a material to allow fluid to move through its pores or interstices. In the context of soil, permeability generally relates to the propensity of a soil to allow fluid to move through its void spaces.

1. According to Darcy's law, the flow rate of fluid (crude oil) q , through a soil of cross-sectional area, A is directly proportional to the imposed gradient, I or

$$\frac{q}{A} i \dots \dots \dots \quad (1)$$

If a constant of proportionality, K is introduced we obtain the equation,

2. The constant, K, the coefficient of permeability, thus, the greater the value of permeability, the greater the flow will be for a given area gradient. However, there are several factors that influence soil permeability: viscosity of oil, size and shape of soil's particles, and degree of saturation and void ratio.
 3. It is also the property of the soil pore system that allows fluid to flow. Generally, the pore size determines whether a soil has high or low permeability. In other words, fluids flow easily through soil with a large pore than soils with small pores because the flow of fluid will be very slow. The concept of permeability is necessary in determining flow characteristics of hydrocarbon in oil.

2.5.7 Porosity: Is the measure of the void space in the soil and a fraction of the volume of voids over the total volume. Its fraction ranges from less than 0.01 for solid granite to more than 0.5 for peat and clay. The degree to which the soil mass is permeated with pores or cavities.

The number, size, shape and distribution of pore influence the soil ability to hold water. Thus, soil porosity is referred to that part of soil volume which is not occupied by soil

particles or organic. It may be represented in percentage by multiplying the fraction by 100.

$$\phi = \frac{V_v}{V_T} \times 100$$

Porosity of surface soil typically decreases as particle size increases but its permeability rate decreases. Thus, an increase in particle size of a soil decreases its porosity and permeability.

2.6 CHEMICAL PROPERTIES OF SOIL

Soil chemical properties are the interaction of various chemical constituents that takes place among soil particles, soil solution and water retained by the soil. Positively charged nutrient molecules, cations are attracted to the negative charges on the soil particles (adsorption). Chemical parameters of crude oil polluted soil are influenced by the pH value, electrical conductivity, total organic carbon, cation exchange capacity and the heavy metals.

Soil pH is one of the most important chemical properties the concentration of free hydrogen ion in the soil matrix. Soils with relatively low concentration of hydrogen ion tend to be acidic while alkaline soils have relatively low concentration of hydrogen ions. Hydrogen ions are made available to the soil matrix by the dissociation of water by the activity of plant roots and by many chemical weathering reactions. Soil fertility is directly influenced by pH through the solubility of many nutrients. At pH lower than 5.5. many nutrients become very soluble and are readily leached from the soil profile.

At high pH, nutrients become insoluble and plants can not readily extract them, thus, maximum soil fertility occurs in the range 6.0 and 7.2.

2.6.1 Soil Organic Matter

It plays an important role in the chemistry of soils. Soil properties associated with soil organic matter includes; structure, macronutrients and micronutrient supply, cation exchange capacity and pH buffering. Organic matter is also a source of energy for micro-organism. Soil organic matter comprises decomposed plant and animals residue. It is a highly mixture of carbon compound that also contain Nitrogen, sulphur and phosphorus. Boele, R., Fabig, H., Wheeler, D. (2001)

O.M is made up humic substance and biochemical compounds humic substances are operationally defined based on their solubility characteristics. Humic acid are soluble in alkaline but not acids solutions. Fulvic acid are soluble on acid are soluble on acid and alkaline solutions and humin is the material that remains after humic acid and fulvic acid extractions. Biochemical compounds includes identifiable organic compounds such organic acid, proteins, polysaccharide, sugar and lipids (Stevenson, 1994).

2.6.2 Cation Exchange Capacity

This is the capacity of the soil for ion exchange of cation between the soil and the soil solution. Cation Exchange Capacity (CEC) is used as a measure of fertility, nutrient retention capacity and the capacity to protect ground water from cation contamination.

Cation can also be easier to understand by first adding the group number. The quality of the positively charge ion (cations) that a clay material or similar material have. It is defined as the degree to which a soil can absorb and exchange cations. Cations are positively charged ions such are NH_4^+ , K^+ , Ca^{2+} , Fe^{2+} etc.

Soil particles and organic matter have negative charges on their surfaces. Mineral cation can adsorb to negative surface charges on the inorganic and organic soil particles. Once adsorbed, the minerals are not easily lost when the soil is leached by water and they also provide a nutrient reserve available to plant roots. These minerals can then be replaced by or exchanged by other cations.

CEC is highly dependent upon soil texture and organic matter content. In general, the more clay and organic matter in the soil, the higher the cation exchange capacity. Clay content depends on CEC because these small particles have a high ratio of surface area to volume. Also CEC of most soil increases with an increase in pH. The order of strength of adsorption in CEC are $\text{Al}^{3+} > \text{Ca}^{2+} > \text{Kg}^{2+} > \text{K}^+ \text{ NH}_4^+ \text{ Na}^+$. (Stevenson, 1994).

2.6.3 Total Organic Carbon

This is the amount of organic carbon bound in an organic compound. It is often used as a non-specific indicator of soil quality. A typical analysis for TOC measures both the total carbon as well as the inorganic carbon. Subtracting the inorganic carbon from the

total carbon yields Total Organic Carbon. Another method of Total Organic Carbon analysis involves removing the inorganic carbon portion first and then measuring the leftover carbon. These methods involve purging and acidified sample with carbon-free air or nitrogen prior to measurement, and so are more accurately called non-purge able organic carbon. Total organic carbon is used as a screening method for petroleum hydrocarbons (crude oil) contamination. TOC was measured in the field (oil spilled site) through wet oxidation using chronic acid and colorimetry. High value of TOC in a contaminated soil indicate Total Petroleum Hydrocarbon (TPH) concentration higher than or above the action level. Ari (1998)

2.6.4 Electrical Conductivity

This is a measure of the dissolved material in an aqueous solution, which relates to the ability of the materials to conduct electricity or electrical current through it. EC is measured in units (ms/cm) or Siemens per unit area. Higher dissolved materials in soil sample, the higher the electrical conductivity of that material. Electrical conductivity can be measured using a meter and probe as well. The probe consists of two metal electrode spaced 1cm apart. A constant voltage is applied across the electrodes resulting in an electrical current flowing through the aqueous sample. Since the current flowing through the water is proportional to the concentration of dissolved ions in water, the electrical conductivity (EC) can be measured. The higher the dissolved ion or salt

concentration, the more conductive the samples and hence the higher the conductivity reading.

2.7 EFFECTS OF OIL SPILLAGE

Oil spillage has negative impact on air, water and soil. According to Rangaswami and Bagyarey (1993), it vitiates the quality of air inhaled by living organism and can also lead to lung diseases in human. In water, it causes death of fish and also contaminates and reduces the quality of water for drinking purposes. Furthermore, a heavily polluted soil remains infertile for about three or more years until the soil loses its toxic effect by degradation. This duration of oil in the soil is a function of many variables such as the types of crude oil, level of pollution, the climates of the area and control method like ploughing fertilizer application (Odu, 1989).

The mode in which petroleum acts on plant is complex and involves both contact toxicity and indirect deleterious effects mediated by interaction of the petroleum with the abiotic factors (like temperature and oxygen) and microbial components of the soil (Rangaswarm and Bagyaray, 1993). Also, Odu (1981) had reported that on farm lands, the effect of oil spill can be observed on food crops such as cassava, yam, vegetable etc. which always exhibit yellowing of leaves (chlorosis). Furthermore, soil fertility is reduced and this result in the poor quality and quantity of output when the survived food crops eventually reaches maturity. Plant normally loses their ability to

photosynthesis as a result of their stems, trunks, and surface of leaves being covered by oil.

2.8 SOIL AND SOIL MICROORGANISMS

The environment consists of all external conditions and factors, living and non-living (chemical and energy) that affect an organism or other specified system during its lifetime of which the air, water and soil are inclusive. Thus, in placing more emphasis on oil, it is defined as a complex mixture of eroded rock, mineral nutrients decaying organic matter, water, air and billions of living organism, most of them microscopic decomposes (Miller, 1996). Also, soil has been defined as the top tool of the earth, and a hectare of fertile cultivated soil may contain as much as 1000kg of micro organisms accounting for about 0.25% by weight of soil (Rangaswami and Baygasaj, 1993).

According to miller (1996), mature soils are arranged in a series of zones called soil horizons, each with a distinct texture and composition that varies with different types of soil. He classified the layer into O, A, B and C horizons. The top layer, the surface litter or O horizon consists mostly of freshly fallen and partially decomposed leaves, twigs, animals waste fungi, and other orgasmic materials. It is normally brown or black in colour. The topsoil layer A horizon is a porous mixture of partially decomposed organic matter (humus) and some inorganic mineral particles. It is usually darker and looser than deeper layer and is the zone where roots of most plant are concentrated. The B

horizon (subsoil) and C horizon (parent material) contains most of a soils inorganic matter. It is mostly broken down rocks consisting of varying mixture of sand, silt, clay, and gravel. The major groups of organism in soil include viruses, bacteria, fungi algae, and Macro fauna such as protozoa and arthropods (Atlas and berthas, 1993). All of which have specific ecological riches and functions, and each contributing to the overall biotic activities of the environment. Hence, some micro organism isolated from hydrocarbon contaminated soil includes actinomycetes, fungi heterotrophic bacteria and phototrophic micro organisms (Odukuma and okpokwasili, 1993). It has also been reported that a large number of heterotrophic bacteria could be isolated from petroleum contaminated soils which include Pseudomonas Achromobacter, Arthrobacter, micrococcus filamentous fungi of the order, macerates (e.g. Cuminghamella) and moniales (e.g. Fusarium, Aspergillums, Penicillin). Together with some yeast e.g. Cladosporium, Candida, and Saccharomycets (atlas, 1981), of these micro organism mentioned, bacteria which are the most numerous organisms in soil, and fungi are particularly important with respect to biochemical transformations.

2.9 PHYSIOLOGY AND BIOCHEMISTRY OF BACTERIA

The development of innovative bioremediation techniques as a functional tool in clean – up of petroleum hydrocarbons pollution of the environment has depended so such on the basic understanding of the physiology and ecology of native bacterial populations

found in such polluted site. Bacteria are the most numerous organisms found in such polluted sites. Bacteria are the most numerous population found in such polluted or anywhere else on earth (Rangaswami and Bagyarasi 1993). According to Paul and clerk (1989), bacteria are classified as prokaryotic organism lacking nuclear membrane, being capable of rapid growth and reproduction, both of which occur by binary fission having sizes ranging from 0.1 to 0.2um existing in rod, coceal, or pleomorphic shape with a biomass of about 500kg / ha to the depth of the root zone, mostly obtaining their energy from the oxidation of organic and inorganic substances. Most of these bacteria and other micro organism exists injured or are killed due to hash environmental conditions. Also they have diverse specific nutrition needs and thus cannot be cultured by conventional methods. Thus the ones cultured are the viable ones. In practice, perhaps 93-95% of all soil organisms may be non-culturable (Roszak and Colwell, 1987). Thus any methodology that relies on obtaining soil organism via a culturable procedure may be sampling a very small substance of the soil population.

2.10 REMEDIATION TECHNIQUES OF OIL IMPACTED SOIL

Remediation of oil impacted soils can be achieved through physical chemical (often jointly referred to as physic-chemical) and biological method (long, 1993). Biological method is preferable due to its less cost and reduced negative impact on the environment.

2.11 BIOLOGICAL METHODS (BIOREMEDIATION).

Bioremediation is a treatment method that makes use of living plants (Phytormendiaton) or organism in the treatment process of oil impacted soil or water. Due to the scope of this study, more emphasis will be layed on microbial bioremediation. Onwurah (2000), reported bioremediation as the process that make use of micro organism (e.g.) bacterial fungi etc, to break down or degrade petroleum hydrocarbons into carbondioxide and water. The microbes used, usually being isolated from natural sites, but their natural capability for breaking down the pollutant is enhanced through other engineered processes. It should thus be noted that the effect of a pollutant in the environment can be mitigated by the resident or indigenous microbiota. In this method, the hydrocarbons are degraded through enhancing the growth of the indigenous bacteria via the addition of oxygen and other nutrients (Onwurah, 2000). This is because appropriate specific pollutant degrading microorganisms are always present at the target sites but however, at low concentrations (bossert and bartha, 1984).

Bioremediation causes less damage to the environment and many result from such clean up technology showing that his process is effective, safe to human and environmentally friendly (onwurah, 2000). It can be done at reduced cost, less time, and with less risk of exposure to hazardous waster for workers and those who live near the site. However, according to Rittmna (1993), bioremediation is still associated with controversy because of uncertainties of working in-situ and its multidisciplinary nature. Other problem

include unpredictability of bioremediation in the field add a void of understanding how to combine molecular biology with the existing engineering practices.

2.12 FACTORS INFLUENCING RATE OF HYDROCARBON BIODEGRADATION IN SOIL

The biodegradation of petroleum and other hydrocarbons in the environment is a complex process whose qualitative and quantitative aspects depends on the nature and amount of oil or hydrocarbons present, the ambient and seasonal environmental conditions, and the composition of the indigenous microbial community (Atlas, 1981).

Consequently the factors affecting hydrocarbon degradation in soil are as follows;

2.12.1 Temperature

Temperature affects the rate of microbial hydrocarbon degradation activities by its effects on the physical nature and chemical composition of the oil, particularly the surface area available for microbial colonization and the rates of hydrocarbon metabolism by microorganisms (Atlas, 1981). A warming trend favors biochemical changes in the soil that are brought about by microbial population. But the problem is that the control of temperature would not be practical to implement except in small scale experimental cases.

2.12.2 Oxygen

The availability of oxygen in soils, sediments, and aquifers is limiting and dependent on the type of soil and whether the soil is water logged or not. If the soil waterlogged, oxygen diffusion will be extremely slow and cannot keep up with the demand of heterotrophic microorganism. To overcome oxygen limitation, it is possible to add hydrogen peroxide in appropriate and stabilized formulation (American Petroleum Institute, 19887). This will supply oxygen to the soil by circulating the hydrogen peroxide ($H_2 O_2$) through the contaminated soil to stimulate the activities of the naturally occurring microorganisms.

2.12.3 Nutrient Availability

The availability of some essential nutrients (mostly Nitrogen and phosphorous) can also affect the degradation of hydrocarbons in soils. According to Atlas and Bartha (1973), many contaminated sites contain organic matter that are rich in carbon but deficient in nitrogen and phosphorus; and for a more rapid biodegradation process, there should be increased amounts of nutrient which can be achieved through nutrients injection to optimize the carbon / nitrogen (C:N) in the site.

2.12.4 Microbial Population

Microorganism are of great importance in the recovery of oil impacted soil or water. Wilson et al. (1985), reported that acclimation of microorganism after prolonged exposure to the polluting crude oil to enhance the existing population aimed at

increasing the rate of biodegradation (Onwurah, 2000) this process can be referred to as bioaugmentation Onwurah (2000), also reported that scientists are now capable of creating super bugs i.e. organisms that can degrade pollutants at extremely rapid rates. The problem is that the introduction of these organisms may fail due to the fact that the introduced microbes often cannot establish a niche in their new environment. They rarely survive beyond a few weeks. He also went on to point out that the microbes can be strongly sorbed by solid surfaces thus creating a difficulty in delivering the introduced organisms to the site of contamination.

2.12.5 Moisture Content

The moisture content of soil can affect the degradation process of hydrocarbons by reducing aeration. According to Rngaswami and Bagyaraj (1993), saturated soils are usually anaerobic and aerobic microbes of which the aerobic ones are more important for biodegradation of hydrocarbons and thus will have a reduced ability to act in waterlogged soils.

2.12.6 pH

According to Rangaswami and Bagyaraj (1993), undisturbed soils usually have fairly stable soil pH values within the range of 6 – 8. Variation of soil pH can occur due to local decomposition of organic residue to acids. But soil organisms are not adversely affected by soil pH unless drastic change occurs like addition of lime to increase pH or when sulphur is added to decrease it. They also reported that optimum biodegradation

tend to occur around pH values of 7.5 – 7.8. Generally, it often happens that one or more of these factors discussed are limiting. For instance the naturally occurring nutrient supply may be less than what is needed for optimum performance of the oil degrading microorganisms being in competition with one another for substrate, water, or growth. Thus a good remediation technique is required for oil polluted soil of which microbial bioremediation is preferable since it focuses on optimizing the activities of oil degrading microorganisms by tackling limitations of microbial growth.

2.13 HEAVY METALS

Heavy metals have direct physiological toxic effect on plants and animals (Botkin et al 1995). Heavy metal is defined or referred to as any metallic chemical element that have a relatively high density and is toxic at low concentration.

Heavy metals are natural component of the environment, but are of serious concern because they are added to soil in a very large quantity. Stoyanova (1998) reported that heavy metals bring anatomical changes in plant cell and also disrupt the metabolic processes of living organism. Some of the prevalent heavy metals are nickel, lead, chromium, vanadium, cadmium, arsenic, zinc etc.

2.13.1 Lead is a bluish–white cationic metal of bright luster. It is soft, malleable and ductile, poor conductor of electricity and it's resistant to corrosion (David, 1998).

Lead occurs in so many chemical state, its usual oxidation state in organic compounds being + 2 and + 4. In natural environment, the divalent form (pb^{2+}) of lead is stable

ionic species of lead (Charles, 1992). Exploration and exploitation of petroleum is one of the major sources of lead in the environment. Lead is common in the industries which has become distributed and mobilized in the soil as a result of human activities such as welding, battery manufacture, spray pointing, lead mining, repair of automobile radiator and glass making.

Lead affects micro-organisms by retarding the heterotopy breakdown of organic matter in plant. The toxicity is localized in the root system. It may be introduced into homes through clothing, shoes by workers etc. the mobilization of lead downward the soil profile could contaminate underground water once an aquifer is contaminated, and it may take several hundred of years for it to cleanse (Onipede, 2002).

2.13.2 Cadmium is attributed to impurities in zinc based oil additives, metal processing and wear of vehicle tires in which cadmium is an impurity in zinc-containing additives. It causes toxicity to man and animals when ingested from highly contaminated food.

Gastro-intestined effects result from the consumption of food highly contaminated with cadmium while high level of exposure through inhalation may cause chronic or acute lungs disease and renal disease. It may also cause damage to the central peripheral nervous systems and to the liver, heart and skeletal muscles.

In recent years, soil cadmium concentration elevated by factors of hundreds were found at smelter site that had been inactive since the middle age. Although, death of sixty –

five (65) women in Japan was reported as a result of high level of contaminated rice consumed by the women.

2.13.3 Arsenic: The relatively high volatility of a number of arsenic compounds means that the geochemical cycle of arsenic contains significant fluxes passing through the atmosphere. Volcanic action is the most important natural source of arsenic, after a low temperature volatilization and on a local scale it will be the dominant atmosphere source. Also the largest single anthropogenic input, representing about 40% of anthropogenic total is copper smelting.

Arsenic compounds have been widely used as pesticides for over a hundred of years, the phytotoxic effects of arsenic compounds made them attractive as herbicides and as desiccants to allow cotton to be easily harvested after defoliation (Pendias et al, 1992). However, there has been concern over the build-up of arsenic residues in the soil and lake sediments which was extensively employed as herbicides to clear aquatic weeds and defoliate seed potatoes.

2.13.4 Chromium: It appears to be relatively innocuous under soil conditions. Its toxicity decreases cations in plants and long term exposure of chromium can cause kidney and liver damage, circulatory and nerve tissue. Chromium often accumulates in aquatic life, adding to the danger of being exposed to high level of chromium.

2.13.5 Nickel: Has recently been defined as essential micronutrient, because of its involvement in enzymatic activity especially in legume (Welch, 1995). In most plants,

nickel is found at the level of 0.5-5ppm with a wide threshold range of 40-246ppm from toxicity symptoms, depending on plant species. Nickel decreases or inhibits photosynthesis and respiration. Also the mobility of Ni^{2+} is pH dependent and other cations and chelating agent can reduce the mobility (Hardiman and Jacoby, 1984).

2.14 CHEMICAL REACTIONS IN THE SOIL

Soil chemistry is the study of the chemical characteristics of soil which is affected by mineral compositions, organic matter and environmental factors. These focused primarily on the chemical reactions in the soil that contribute to pedogenesis or that affect plant growth. Soil chemistry is very vital in predicting the fate, mobility and potential toxicity of contaminants in the environment.

When crude oil is spilled or released into the soil, chemical reactions can occur and that may increase or decrease leveling contaminant toxicity. These reactions include;

- Oxidation and reduction reaction.
- Precipitation (Onipede, 2002)

Abundance; aluminum, calcium, iron, sodium, potassium, magnesium and titanium. Trace metals are present in few milligrams per kilogram in the soil (mg/kg), though they lack in abundance but significant. Lead is widely used as additive in petroleum industries and is very toxic that some quantity of lead can destroy life.

The form in which metals exist in nature is related to its reactivity. The trace metals exist in a combined form as oxides or sulphides or in an uncombined form. Most metals

found in combined forms of more or less definite chemical composition known as “mineral”. Often these minerals are found mixed with earthly materials as ore (Arikens, 2002).

2.15 ENVIRONMENTAL IMPACT OF CRUDE OIL IN THE SOIL.

An oil contaminated soil affects the microbial activities and other associated processes. The effect that could associate with crude oil contamination is poor wetting ability and aeration in the soil and the toxic effect on nutrients content of a given soil.

When oil penetrates into the soil, some of its hydrocarbon content evaporates into the atmosphere very quickly and others more slowly. The remaining hydrocarbon content of the oil generally slicks to the topsoil and will eventually form a tar ball (Odu, 1989).

The degree of penetration is a function of the type and nature of soil in type of oil (weaver, 1995). Low viscosity oil will rapidly penetrate into dry porous soil such as coarse sand and so reduce the surface spread.

Oil released in large quantities at the soil surface can penetrate through the soil surface can penetrate through the soil with a drastic effect on the texture, percent organic matter, pH and cation exchange capacity of the soil since the released quantity is so large, downward migration occurs with all soil pores being saturated with petroleum or its by-product because oil is generally not miscible with water.

During percolation, soil water contact residual saturation. Some of the chemicals are released from petroleum and its products and are now dissolved in the soil or ground

water. Also, soil aggregate are broken down, the soil becomes hard and waxy in appearance when it is dry. Such a soil may resist wetting from the surface and when they are wetted tends to remain wet, thus, the crumb structure of the soil texture is lost and becomes puddle. The bulk density of the contaminated soil is reduced and the microspores are increased due to increased organic matter in the soil. The soil becomes acidic and reducing condition develops as a result of ferrous ions and manganese accumulation.

Hutchison (1994) stated that the presence of oil in the soil increases its temperature, and he noted also that an increase in soil temperate from 1°C to 10°C can reduce plant growth.

However, fluctuation in the microbial population in crude oil polluted soil will almost certainly influence the nutrient level of soil and the growth rate of flora in that area. The increase of the exchangeable elements in soil does not only affect micro-organisms but also depress the yield of some plants such as cereals and legumes to grater extent. Thus, the reducing conditions and resulting increase in exchangeable manganese to toxic elements seems to explain much of the damages to plant growth. The damage done to plant may include a change in the hydrostatic conditions of soil which adversely affect the soil plant water relation.

The inability of the soil to absorb water in an oil polluted soil is as a result of hydrophobic nature of the soil. Oil spilled in the soil displaces water, air and at the same

time occupy the natural pore spaces of the soil (Roscoe et al, 1989). Crude oil is a good source of contaminants such as heavy metals and thus when crops absorb the metals in excess will not thrive. Heavy metals poses serous health hazards to human beings through direct absorption and food chain. Once absorbed, these metals concentrate and exposure to such heavy metal at high concentration may result in hypertension, heart enlargement, cancer, genetic mutation and death (Arikens, 2002).

Oil spilled on the soil hinders fertility and agricultural productivity because the activities of micro-organisms in the soil which helps in fixing most of the organic nutrient needed by growing plants are drastically affected. Spread of oil on soil surface also prevents penetration of oxygen and sunlight which is essential for photosynthesis and survival of soil plants and micro-organisms.

CHAPTER THREE: RESEARCH METHODOLOGY

3.0 MATERIALS AND METHOD

3.1 STUDY AREA

This study was carried out in Bomu community in Rivers –State Nigeria. The site is geographically located between lat 4° 5'E and 4° and 7°30'E and 7°00'E (Appendix 7 & 8)

3.1.1 Geology

Bomu is underlined by the Benin formation (Obiukwu, 1999); The Benin formation is built of an alternating layers of sands, sandstone, and loam with some clay. The study components in most areas from more than 90% of the sequence of the layers permeability, transivity and storage coefficient.

3.1.2 Soil

The soil of the study area belongs to the ferratic soils. They are old soils, highly watered and leached with a large mineral reserve. The shallow subsurface soil is sand and loamy soil. The texture in the upper 40 to 60 cm is sandy loam, changing to sandy clay below. (Shell Petroleum Development Company, 2002).

3.1.3 Climate

The Bomu area experiences two distinct seasons; a dry season in November-march and a rainy season in April- October. (Obiukwu, 1999),

The rainfall amount is about 2500mm per annum (Federal Ministry of Aviation, 1999).

The lowest mean monthly temperature values were 27.4°30.70C for the rainy season.

High mean monthly temperature of 31°-35°C occurred mostly in dry season.

3.1.4 Vegetation of the Study Area

The area falls within a tropical rain forest, but because of the interest of agriculture, only patches of forest are found along with farmland, and fallow land. The area is presently dominated by grasses. Scattered stands of oil palm and other economic trees can also be found.

3.1.5 Land Use

Land in this area is mostly used for agriculture, mixed cropping, being apparently the most common method of agriculture. Lands are also used for settlement and other activities.

3.2 SAMPLING STRATEGY

Three sampling points shall be designated at the post spilled site and one sampling point designated at a control location. At each sampling point, soil samples shall be collected at depths of 0-15cm, 15-30cm and 30-45cm, with the aid of soil auger.

Therefore, the soil samples so collected will be transferred to a well labeled sterile pollution bay, and taken to the laboratory for further analysis.

3.2.1 LABORATORY ANALYSIS

Various methods were used in analyzing different parameters (Soil Ph, Total Petroleum Hydrocarbon and Trace Metals).

1) METHOD FOR TPH

Extraction

2gm of samples were weighed into a clean extraction container. 10ml of extraction solvent (dichloromethane) was added into the samples, mixed thoroughly, and allowed to settle.

The mixture was carefully filtered into clean solvent rinsed extraction bottle, using filter paper into buchrer funnels.

The extracts were concentrated to 2ml and then transferred for clean up separation.

Cleanup/ Separation

1cm of moderately packed glass wool was placed at the bottom of 10mm ID x 250mm long chromatographic column.

Slurry of 2g activated silica in 10ml methylene chloride was prepared and placed into a chromatographic column. To the top of the column was added 0.5cm of sodium sulphate, the column was rinsed with additional 10ml of methylene chloride.

The column was prediluted with 20ml of dichloromethane; this was allowed to flow through the column at the rate of about 2mins until the liquid in the column was just above the sulphate layer. Immediately 1ml of the extracted sample was transferred into

a column. The extraction bottle was rinsed with 1ml of dichloromethane and added to the column as well.

The stop clock of the column was opened and the element was collected with a 10ml of graduated cylinder. Just prior to exposure of the sodium sulphate layer to air, dichloromethane was added to the column in 1-2ml increments. Accurately measured column of 8-10ml of the element was collected and was labeled aliphatic.

Gas Chromatographic Analysis

The concentrated aliphatic fraction was transferred into labeled glass vials with Teflon or rubber crimp caps for G C analysis.

1ul of this concentrated sample was injected by means of hypodermic syringe through a rubber septum into the column. Separation occurs as the vapour constituent partition between the gas liquid phase.

The sample was automatically detected as it emerges from the column (at a constant flow rate) by the FID detector whose response is dependent upon the composition of the vapour.

2) SOIL pH DETERMINATION

APPARATUS: Glass-electrode PH meter

REAGENTS

[A] 0.01M calcium chloride

[B] Distilled

[C] 1N potassium chloride

PROCEDURES

Soil PH in H₂O [1:1soil to water ration]

- 1) Weigh 20g of air-dry soil (passed 2-mm sieve) into a 50-ml beaker. Add 20ml of distilled water and allow to stand for 30minutes and stir occasionally with a glass rod.
- 2) Insert the electrodes of the PH meter into the partly settled suspension and measure the PH. Do not stir the suspension during measurement.
- 3) Report result as ‘soil PH measured in water’'

Note [1] The electrodes should be rinsed with deionized water and wiped dry with a clean tissue or filter paper after each reading

[2]The PH meter should be calibrated with pH 7.0 pH 4.0 buffer before use.

Soil pH in 0.01M cacl₂

- [1] Prepare a 1:2 (soil 0.01M cacl₂) suspension (10g of soil and 20ml of solution).
- [2] Let the suspension stand for about 30nminutes and stir occasionally with a glass rod.
- [3] Measure pH and report result as pH measured in 0.02M cacl₂.

Soil pH in 1N KCl (1.1 soil to solution ratio)

- [1] Add 20ml of 1N Kcl to 20g of soil sample and equilibrate for 30 minutes with occasional stirring.
- [2] Determine pH and pH meter.

3) PROCEDURE FOR METAL ANALYSIS

Soil/ sediment pre-treatment:

Weigh 5g of air dried, 2mm sieved soil / sediments sample into a 100ml beaker. Add 2ml HNO₃ (aq) and 6ml HCL (aq) in the ratio 1:3 to already weighed soil / sediments sample. Digest the sample by heating on a heating mantle, ensuring the mixture obtains near dryness so as to enable proper leaching of the soil / sediments sample.

To digested sample, filter using (distilled H₂O) to dilute or rinse the mixture through a filter paper into a 50ml volumetric flask. (Note filter paper type: whatman no. 42, 150mm diameter). With distilled water make up to 50ml mark digested filtrate in the volumetric flask. Present digested soil/sediments sample to the AAS so that the concentrations of the respective metals of interest can be read out.

The AAS (atomic absorption spectrophotometer) is been calibrated using standard solutions (solutions of known concentrations) or each of the metals of interest, for example: cu- 1, 3 and 5ppm, Zn- 1 and 2ppm, Cr- 2and 5ppm, Pb-0.5 and 1.0ppm e.t.c.

For metals like Fe, Ca, Zn, it is likely that their concentrations could be higher than the concentration of the highest calibration standard. This requires that we do serial dilutions of (x10), (x20), (x50) etc as the case may be.

3.3 STATISTICAL ANALYSIS

The equality of means of sampling points shall be established of variance (ANOVA). The inter-relationship existing between the physiochemical variables will be investigated with the use of Pearson Product Moment Correlation Co-efficient (r). And data will further be represented graphically.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 VARIATION IN PHYSIOCHEMICAL PARAMETERS

Results of the physicochemical characteristics revealed wide variations in total petroleum hydrocarbons (TPH), phosphate, nitrate, zinc, magnesium, chromium, lead, and calcium concentrations, though narrow variations were also observed in pH, sulphate, iron, copper, cobalt, and cadmium concentrations (Table 4.1).

Table 4.1 Descriptive statistics of the physicochemical characteristics of soils of Bomu from the control and polluted sites A and B.

PARAMETERS	MINIMUM	MAXIMUM	MEAN	STD. ERROR
pH	4.10	5.72	4.82	0.19
TPH	202.10	32142.00	10326.86	4376.40
Nitrate	1.20	7.30	3.42	0.67
Phosphate	7.90	148.00	45.54	18.49
sulphate	0.50	5.00	2.42	0.53
Zn	2.89	19.78	11.35	2.45
Fe	1048.00	4668.60	2614.02	334.10
Mg	11.76	60.35	32.25	5.40
Cu	0.03	5.90	2.40	0.72
Cr	0.03	7.62	2.21	0.97
Co	0.00	0.89	0.21	0.09
Ni	0.00	3.04	1.39	0.35
Pb	3.15	17.60	7.68	1.47
Cd	0.01	0.28	0.11	0.02
Ca	8.18	98.96	45.88	11.51

The pH ranged between 4.10 and 5.72 (4.82 ± 0.19), with highest concentration (5.72) recorded in sampling location 3 at the depth of 30-45cm and the least value of 4.1 recorded in sampling location 1 at the depth of 0-15cm (Fig. 4.1).

The TPH ranged between 202.10 and 32142.00 (10326.86 ± 4376.40), with highest concentration (32142) recorded in sampling location 2 at the depth of 15-30cm and the least value of 202.1 recorded in sample location 3 at the depth of 30-45cm (Fig. 4.2)

The Nitrate ranged between 1.02 and 7.30 (3.42 ± 0.67), with highest concentration (7.2) recorded in sampling location 3 at the depth of 30-45cm and the least value (1.2) recorded in sampling location 1 at the depth of 0-15cm. (Fig. 4.3)

The Phosphate ranged between 7.90 and 148.00 (45.54 ± 18.48), with highest concentration (148) recorded in sampling location 2 at the depth of 15-30cm and the least value (7.9) recorded in sampling location 1 at the depth of 0-15cm. (Fig 4.4)

The Sulphate ranged between 0.50 and 5.00 (2.42 ± 0.53), with highest concentration (5) recorded in sampling location 3 at the depth of 30-45cm and the least value (0.5) recorded in sampling location 1 at the depth of 0-15cm. (Fig 4.5)

The zinc ranged between 2.89 and 19.78 (11.35 ± 2.14), with highest concentration (19.78) recorded in sampling location 2 at the depth of 15-30cm and the least value (2.88) recorded in sampling location 1 at the depth of 0-15cm. (Fig 4.6)

The Iron ranged between 1048.00 and 4668.60 (2614.02 ± 33.10), with highest concentration(4668.6) recorded in sampling location 1 at the depth of 0-15cm and the least value(1048) recorded in sampling location 2 at the depth of 15-30cm. (Fig 4.7)

The Magnesium ranged between 11.76 and 60.35 (32.25 ± 5.40), with highest concentration (60.35) recorded in sampling location 1 at the depth of 0-15cm and the least value (11.76) recorded in sampling location 1 at the depth of 0-15cm. (Fig 4.8)

The copper ranged between 0.03 and 5.90 (2.40 ± 0.72), with highest concentration(5.9) recorded in sampling location 2 at the depth of 15-30cm and the least value (0.03) recorded in sampling location 3 at the depth of 30-45cm. (Fig 4.9)

The chromium ranged between 0.03 and 7.62 (2.21 ± 0.97), with highest concentration (7.62) recorded in sampling location 1 at the depth of 0-15cm and the least value (0.003) recorded in sampling location 3 at the depth of 30-45cm. (Fig 4.10)

The cobalt ranged between 0.00 and 0.89 (2.21 ± 0.09), with highest concentration(0.89) recorded in sampling location 1 at the depth of 0-15cm and the least value recorded in sampling location 3 at the depth of 30-45cm. (Fig 4.11)

The Nickel ranged between 0.00 and 3.04 (1.39 ± 0.35), with highest concentration (3.04) recorded in sampling location 2 at the depth of 15-30cm and the least value (0.004) recorded in sampling location 3 at the depth of 30-45cm. (Fig 4.12)

The Lead ranged between 3.15and 17.60 (7.68 ± 1.47), with highest concentration (17.6) recorded in sampling location 1 at the depth of 0-15cm, and the least value (3.15) recorded in sampling location 2 at the depth of 15-30cm. (Fig 4.13)

The Cadmium ranged between 0.01and 0.28 (0.11 ± 0.02), with highest concentration (0.28) recorded in sampling location 1 at the depth of 0-15cm and the least value (0.01) recorded in sampling location 3 at the depth of 30-45cm. (Fig 4.14)

The Calcium ranged between 8.18and 98.96 (45.88 ± 11.51), with highest concentration (98.96) recorded in sampling location 2 at the depth of 15-30cm and the least value (8.18) recorded in sampling location 1 at the depth of 0-15cm. (Fig 4.15)

4.2 RELATIONSHIP BETWEEN PHYSIOCHEMICAL PARAMETERS

A test of relationship using pearson correlation (table 4.2) shows that total petroleum hydrocarbon correlated positively with PO₄ ($r= 0.992$), Zn ($r=0.848$), Ni ($r=0.889$) at $p<0.01$ while Cu ($r=0.684$) correlated positively at $p<0.05$.

TABLE 4.2 CORRELATION MATRIX OF PHYSIOCHEMICAL PARAMETERS.

	pH	TPH	Ni	PO ₄ ²⁻	SO ₄ ²⁻	Zn	Fe	Mg	Cu	Cr	Co	Ni	Pb	Cd
pH														
TPH	-0.258													
Nitrate	.898**	-.519												
Phosphate	-0.208	.992**	-.480											
Sulphate	.917**	-.062	.778*	.010										
Zn	-0.005	.848**	-.211	.811**	0.009									
Fe	-.093	-.306	.000	-.316	-.404	-.043								
Mg	.618	-.075	.574	.097	0.334	0.435	0.446							
Cu	-.428	.684*	-.564	.665	-.468	0.678*	0.364	0.084						
Cr	-.519	-.231	-.293	-.260	-.724*	-.088	0.787	0.098	0.391					
Co	-.277	.217	-.203	.163	-.469	.500	0.669	0.474	0.541	0.713*				
Ni	-.269	.889**	-.455	.844**	-.241	.945	0.007	0.219	0.829**	0.021	0.484			
Pb	-.146	-.263	.345	-.308	-.188	.217	0.751*	0.746*	0.253	0.631	0.732*	0.151		
Cd	-.283	.159	-.241	.111	-.543	.404	.780*	0.518	0.701*	0.787*	0.862**	0.509	0.777	
Ca	.080	.355	-.166	.272	0.004	.512	-.218	0.322	0.083	0.363	0.124	0.443	-0.048	0.065

** = Significantly different at p < 0.01

* = Significantly different at p < 0.05

pH correlated positively at p<0.01 with Nitrate (r=.898) and sulphate (r=0.917).

Total Petroleum Hydrocarbon correlated positively at p<0.01 with phosphate (r=0.992), Zn (r=0.848), Ni (r=0.889) and correlated positively at p<0.05 with Cu (r=0.778).

Nitrate correlated positively at p<0.05 with sulphate (r=0.778). Phosphate correlated positively at p>0.01 with Zn (r=0.811) and Ni (r=0.778) Sulphate correlated negatively at p<0.01 with Cr (r=-0.724).

Zinc correlated positively at p<0.01 with nickel (r=0.945) and correlated positively at p<0.05 with Cu (r=0.678).

Iron correlated positively at $p<0.05$ with Cu ($r=0.678$), Co ($r=0.669$), Pb ($r=0.751$) and Cd ($r=0.780$).

Magnesium correlated positively at $p<0.05$ with Pb ($r=0.746$).

copper correlated positively at $p<0.01$ with Ni ($r=0.829$) and correlated positively at $p<0.05$ with Co ($r=0.701$).

chromium correlate positively at $p<0.05$ with Co ($r=0.713$).

cobalt correlated positively at $p<0.05$ with Pb ($r=0.732$) and correlated positively at $p<0.01$ with cadmium ($r=0.862$).

Nickel didn't have any correlation.

lead correlated positively at $p<0.05$ with Cd ($r=0.777$).

While Cd and Ca Nil.

A further examination of the observed relationship between Total Petroleum Hydrocarbon (TPH) and phosphate, Zn, Cu, Ni, using linear regression revealed high and average association.

LINEAR REGRESSION: This is used to model the value of a dependent scale variable based on its linear relationship with one or more parameters.

FIGURE 4.16 Regression plot between Total Petroleum Hydrocarbons and Phosphate.

From the regression plot, the variability of phosphate increases with increase in TPH concentration. And very strong relationship exist between TPH and Phosphate ($R_{\text{linear}}=0.984$).

From the coefficient table (appendix 1) Phosphate concentration is expected to increase by $0.004 \times \text{TPH concentration} + 2.277$. For example, if TPH concentration increases by 2mg/kg the expected phosphate concentration will be $=0.004 \times 2 + 2.277 = 2.29$. i.e for every unit increase in TPH, phosphate will increase by 1.14mg/kg.

FIGURE 4.17 Regression plot between Total Petroleum Hydrocarbons and Zinc.

From the regression plot, the variability of Zinc increases with increase in TPH concentration. And not very strong relationship exist between TPH and Zinc ($R_{\text{linear}}=0.719$).

From the coefficient table (appendix 2) zinc concentration is expected to increase by $0.000 \times \text{TPH concentration} + 7.077$. For example, if TPH concentration increases by 2mg/kg the expected zinc concentration will be $=0.000 \times 2 + 7.077 = 7.07$. i.e for every unit increase in TPH, zinc will increase by 0.035mg/kg.

FIGURE4.18 Regression plot between Total Petroleum Hydrocarbons and copper.

From the regression plot, the variability of copper increases with increase in TPH concentration. And an average relationship exist between TPH and copper ($R_{\text{linear}}=0.468$).

From the coefficient table (appendix 3) copper concentration is expected to increase by $0.000 \times \text{TPH concentration} + 1.223$. For example, if TPH concentration increases by 2mg/kg the expected copper concentration will be $=0.000 \times 2 + 1.223 = 1.22$. i.e for every unit increase in TPH, copper will increase by 0.16mg/kg.

FIGURE 4.19 Regression plot between Total Petroleum Hydrocarbons and nickel.

From the regression plot, the variability of nickel increases with increase in TPH concentration. And an average relationship exist between TPH and copper ($R_{\text{linear}}=0.79$).

From the coefficient table (appendix 4) nickel concentration is expected to increase by $0.0000707 \times \text{TPH concentration} + 0.661$. For example, if TPH concentration increases by 2mg/kg the expected copper concentration will be $=0.0000707 \times 2 + 0.661 = 0.66$. i.e for every unit increase in TPH, nickel will increase by 0.33mg/kg.

4.3 SPATIAL VARIATIONS IN PHYSIOCHEMICAL PARAMETERS

This gave a P value of [$F_{(2,02) < F_{(3,95)}$] at $p < 0.05$ thus giving criteria to the acceptance of the null H_0 (appendix 5)

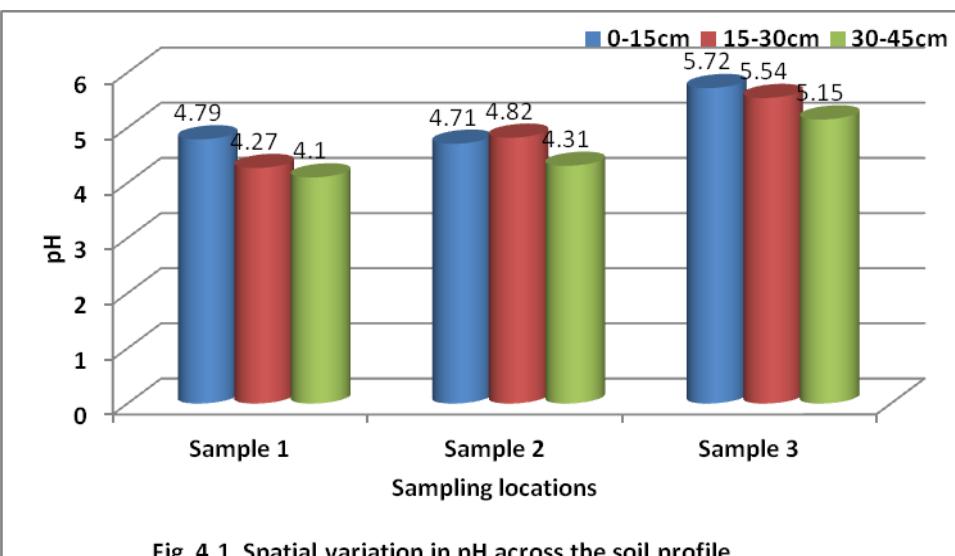


Fig. 4.1. Spatial variation in pH across the soil profile

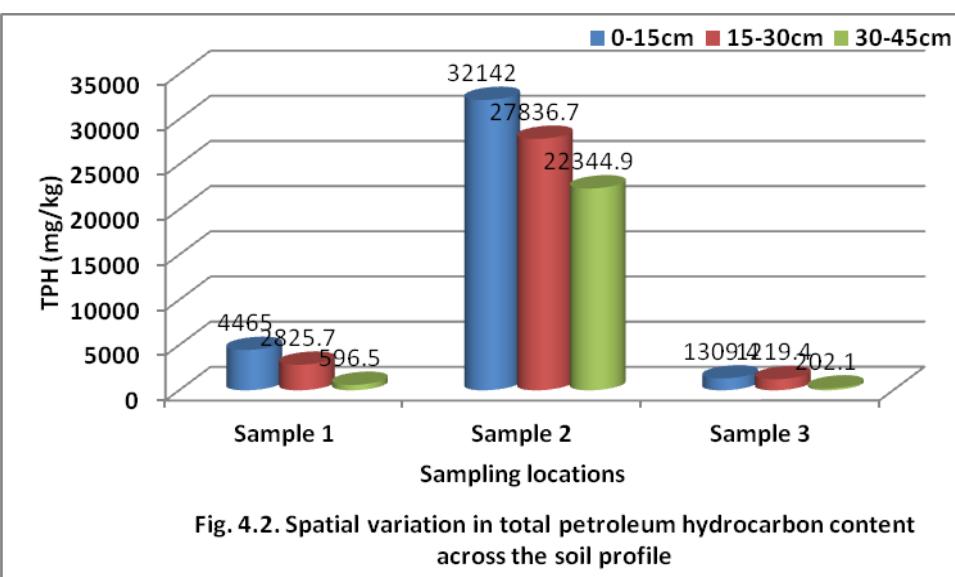
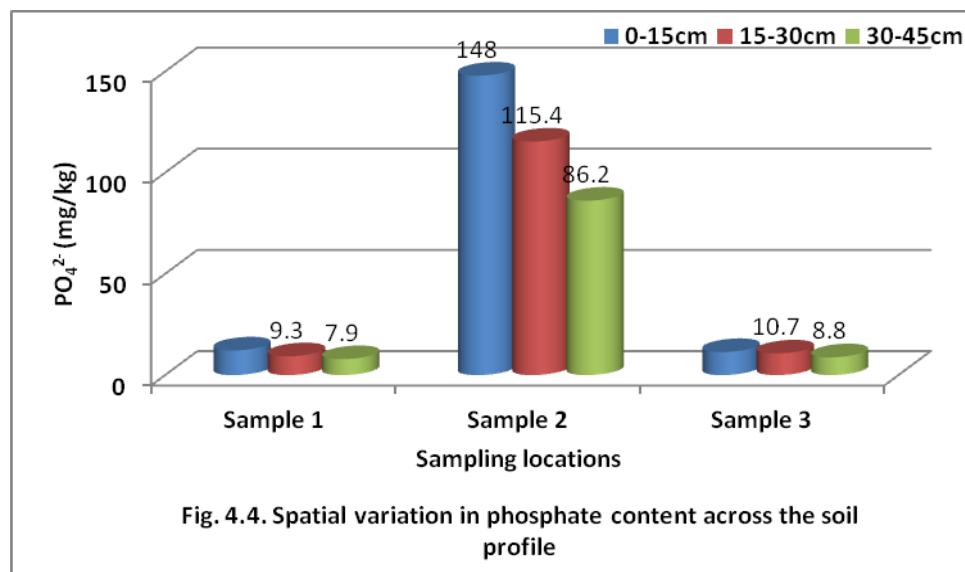
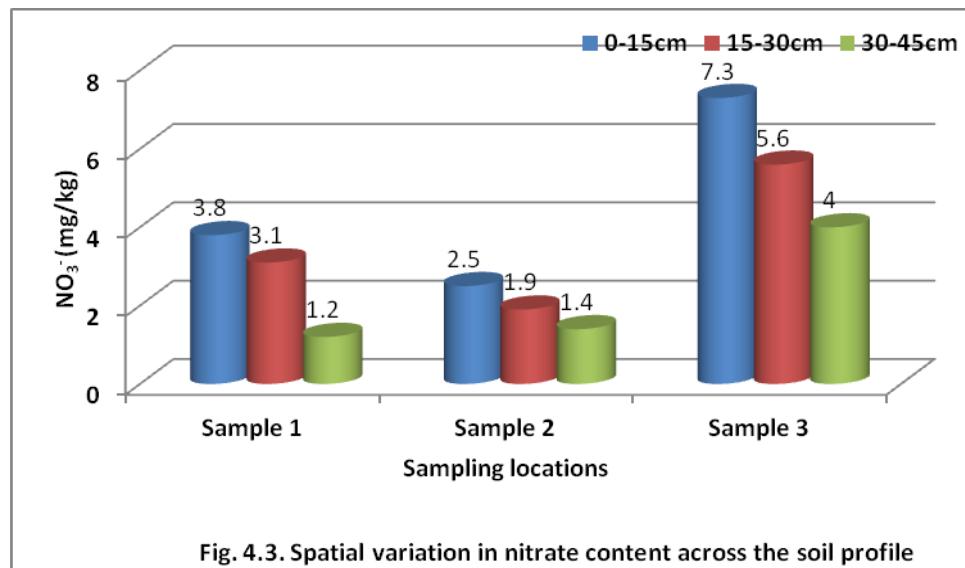


Fig. 4.2. Spatial variation in total petroleum hydrocarbon content across the soil profile



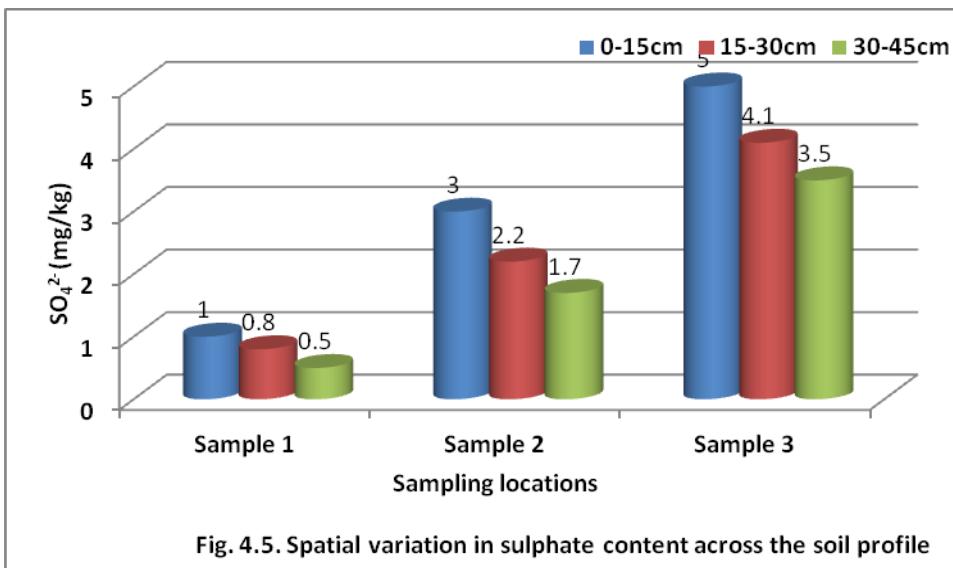


Fig. 4.5. Spatial variation in sulphate content across the soil profile

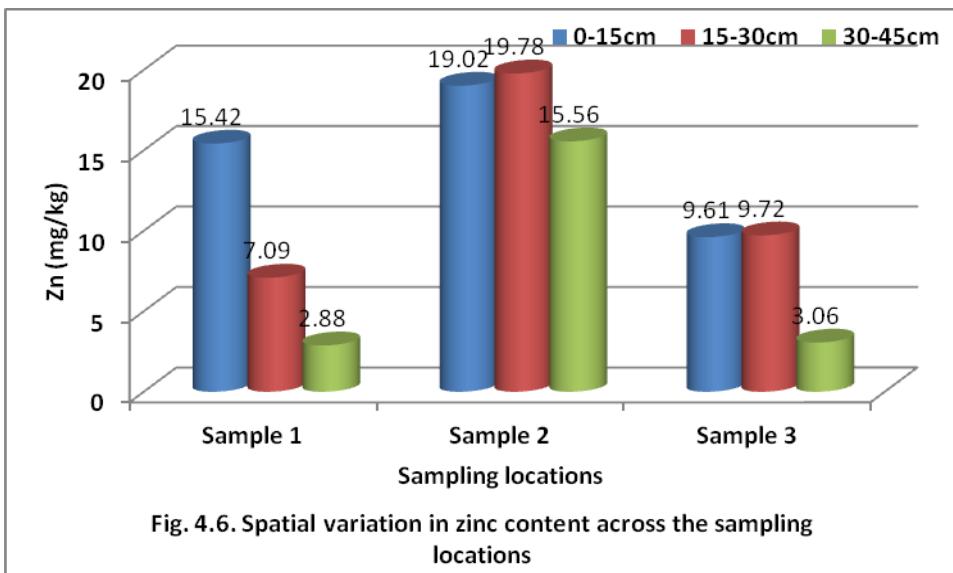


Fig. 4.6. Spatial variation in zinc content across the sampling locations

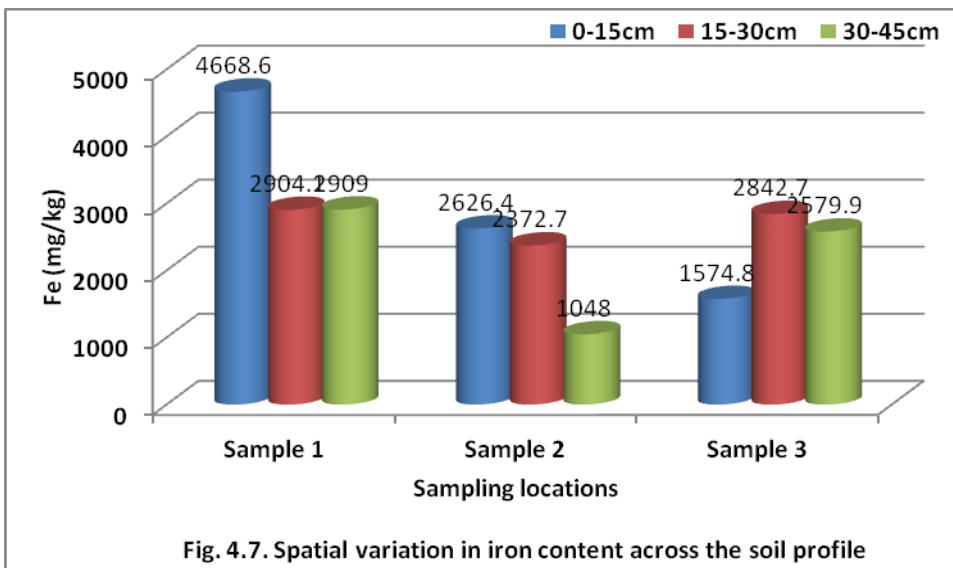


Fig. 4.7. Spatial variation in iron content across the soil profile

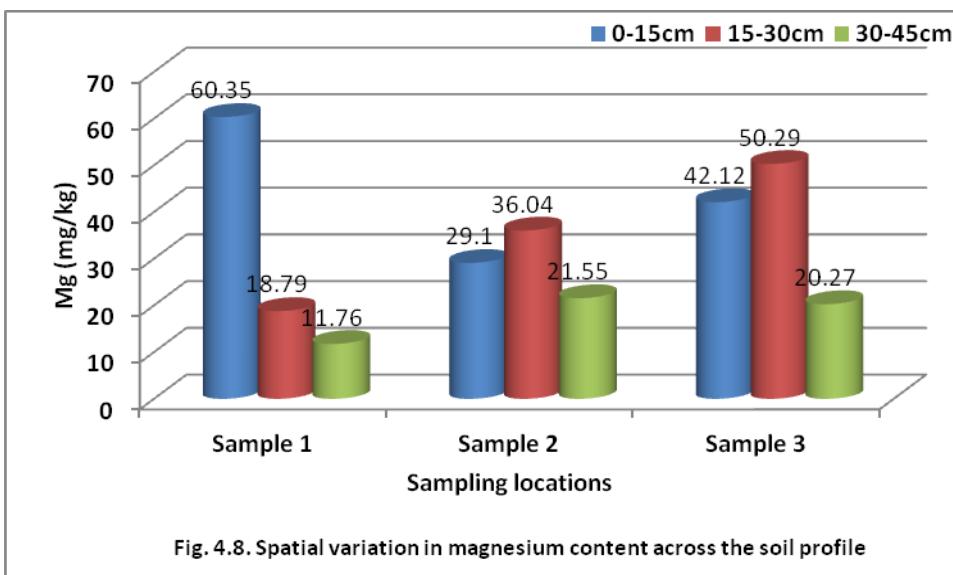


Fig. 4.8. Spatial variation in magnesium content across the soil profile

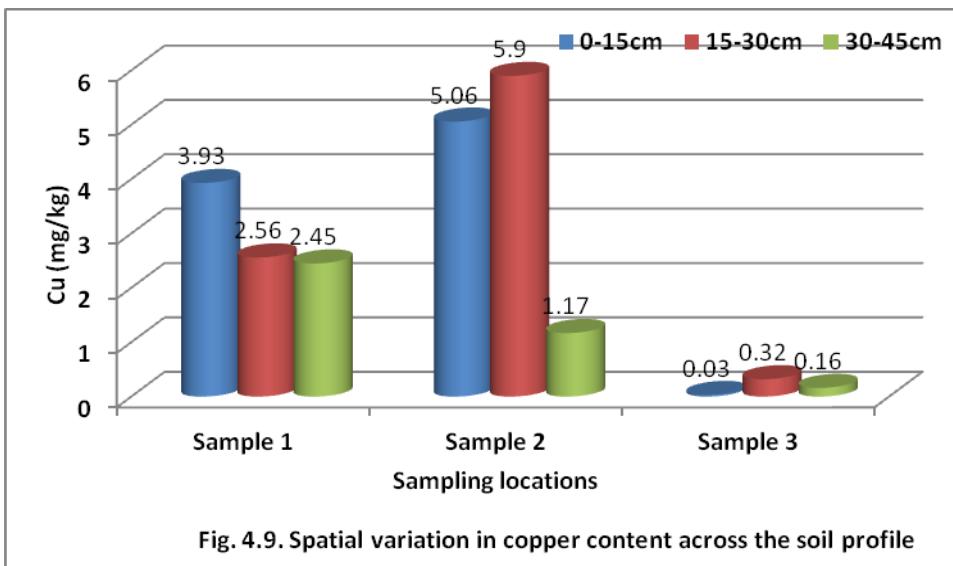


Fig. 4.9. Spatial variation in copper content across the soil profile

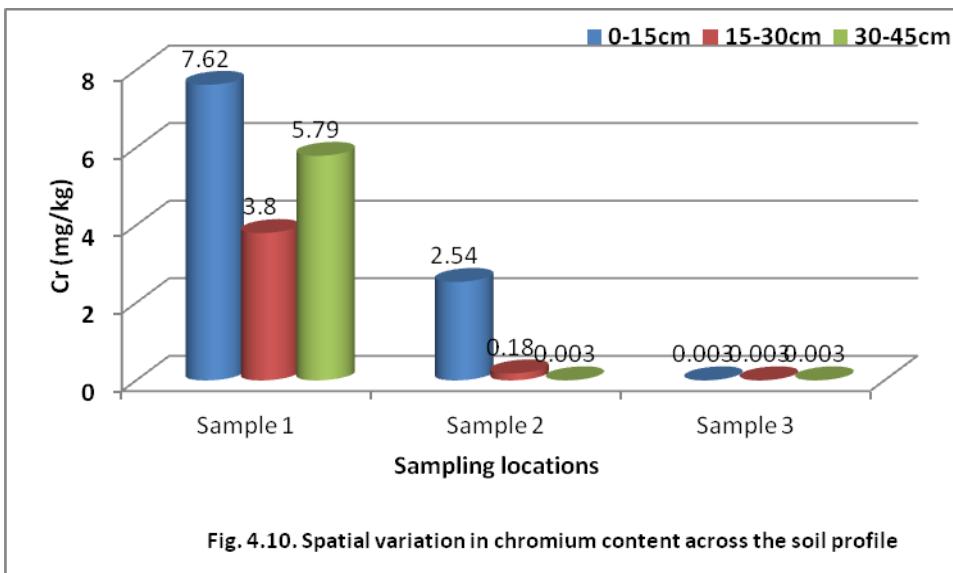


Fig. 4.10. Spatial variation in chromium content across the soil profile

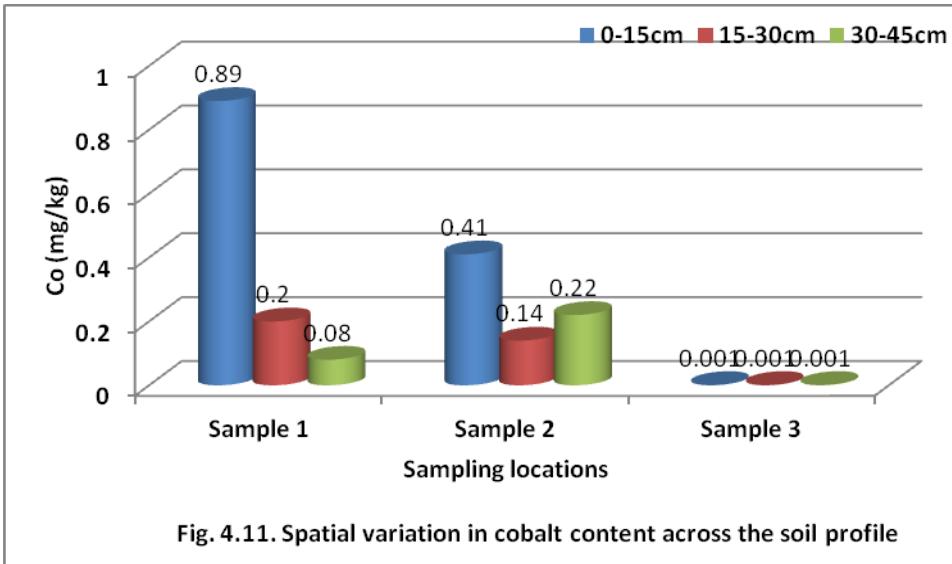


Fig. 4.11. Spatial variation in cobalt content across the soil profile

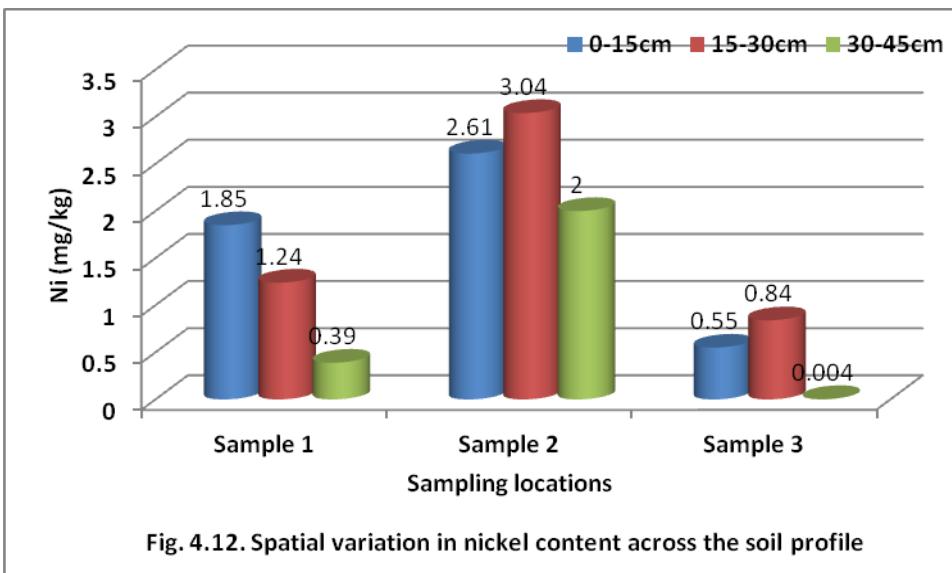


Fig. 4.12. Spatial variation in nickel content across the soil profile

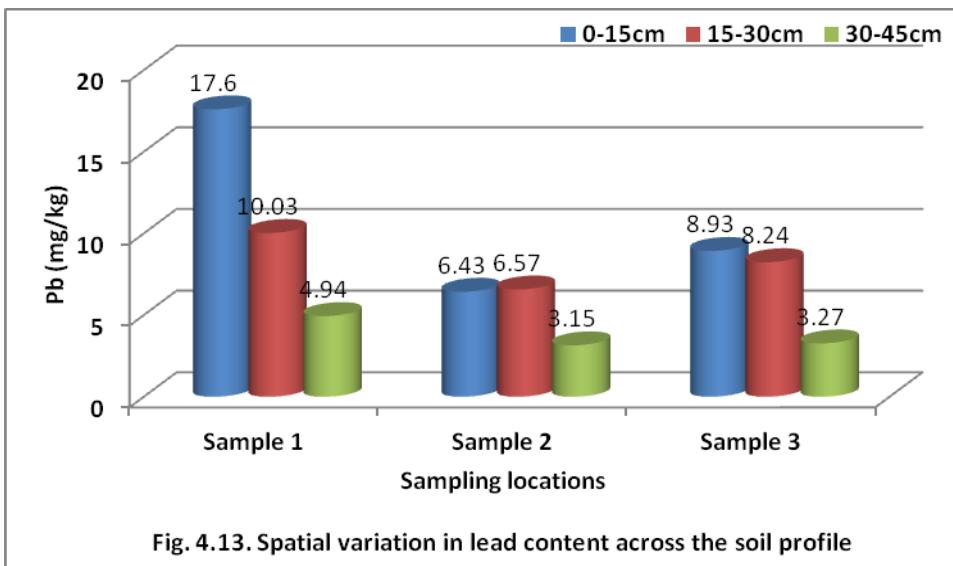


Fig. 4.13. Spatial variation in lead content across the soil profile

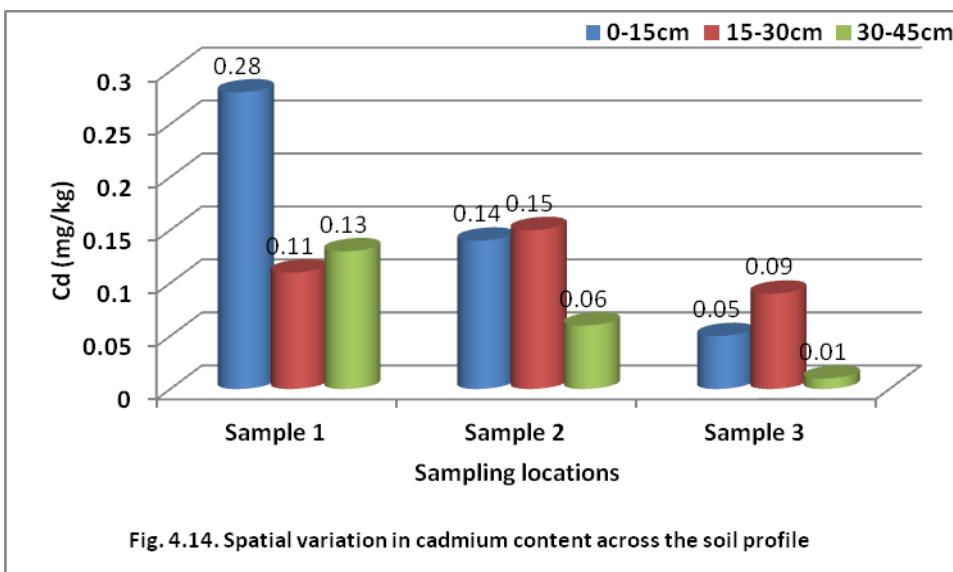


Fig. 4.14. Spatial variation in cadmium content across the soil profile

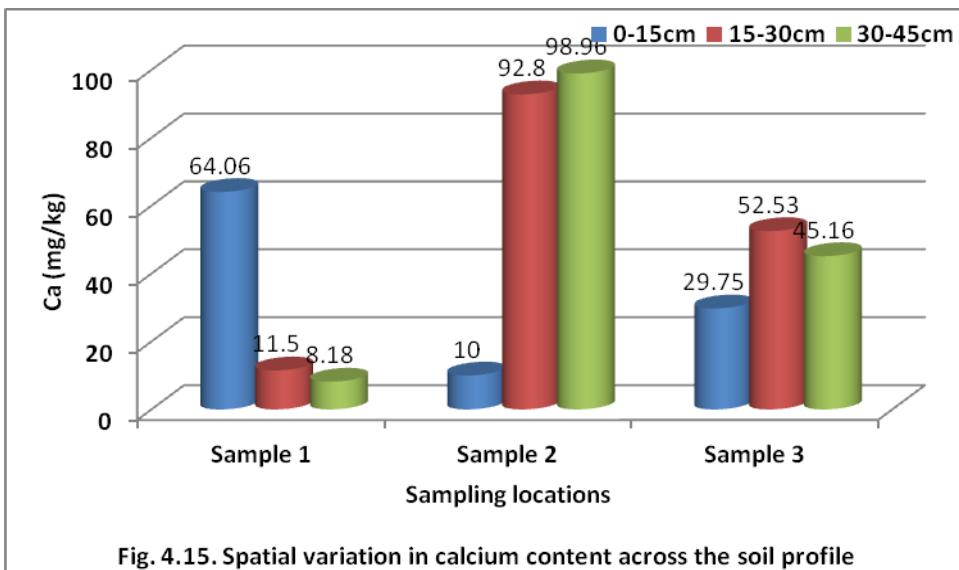


Fig. 4.15. Spatial variation in calcium content across the soil profile

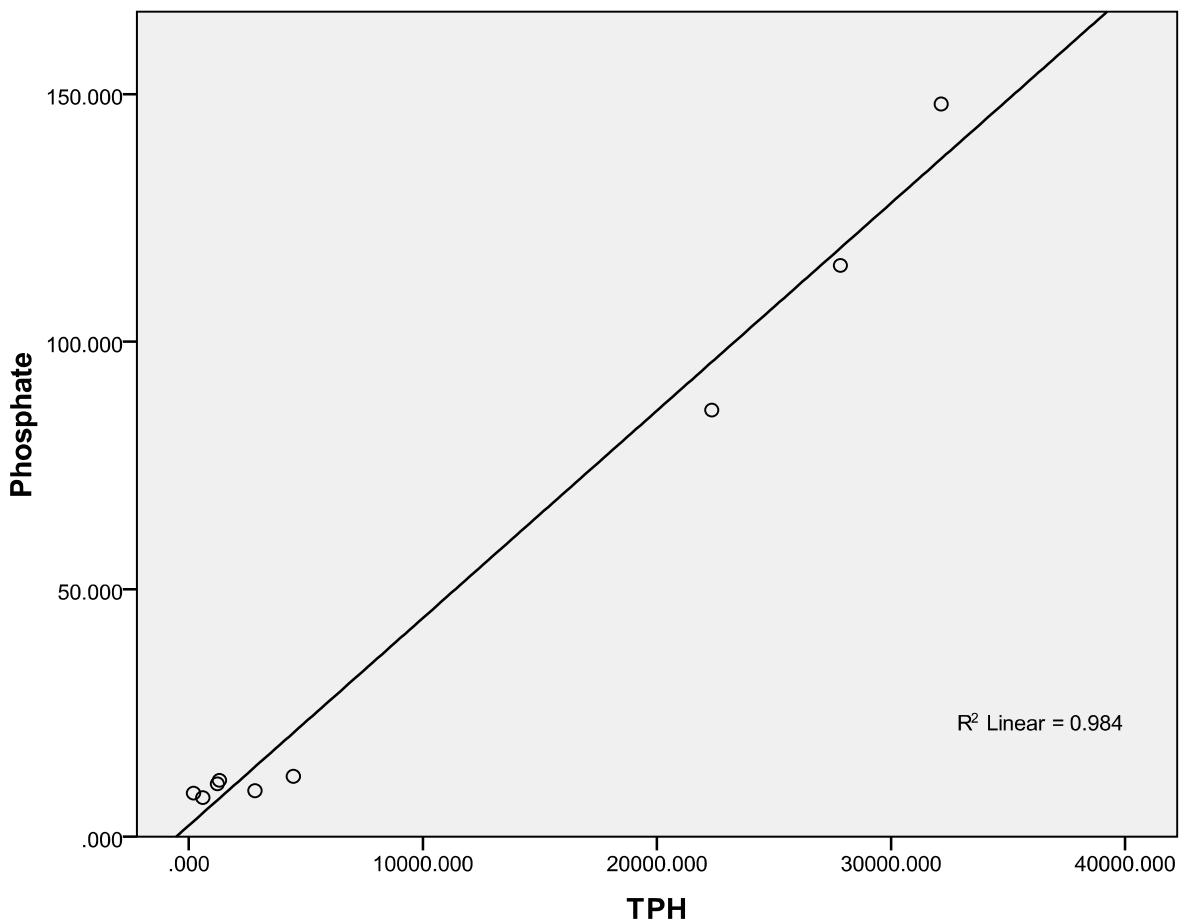


FIGURE 4.16 Regression plot between Total Petroleum Hydrocarbons and Phosphate.

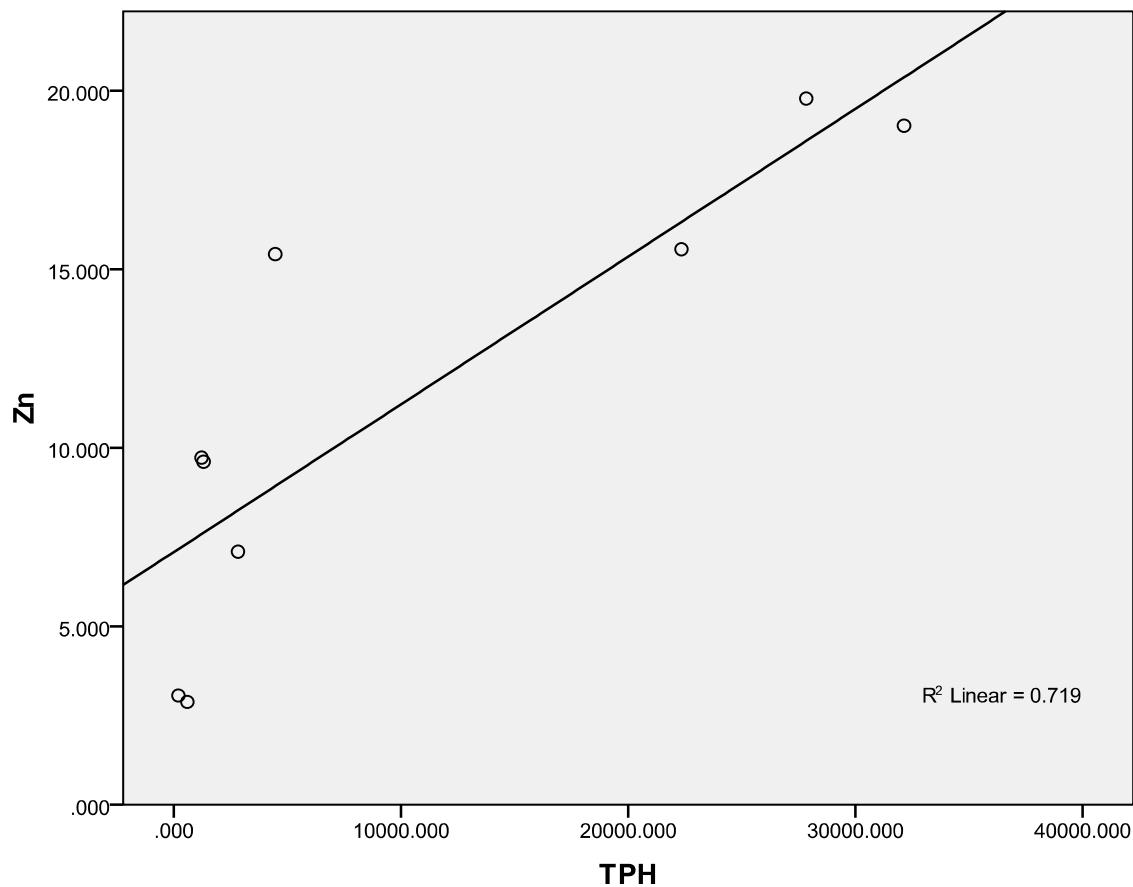


FIGURE 4.17 Regression plot between Total Petroleum Hydrocarbons and Zinc.

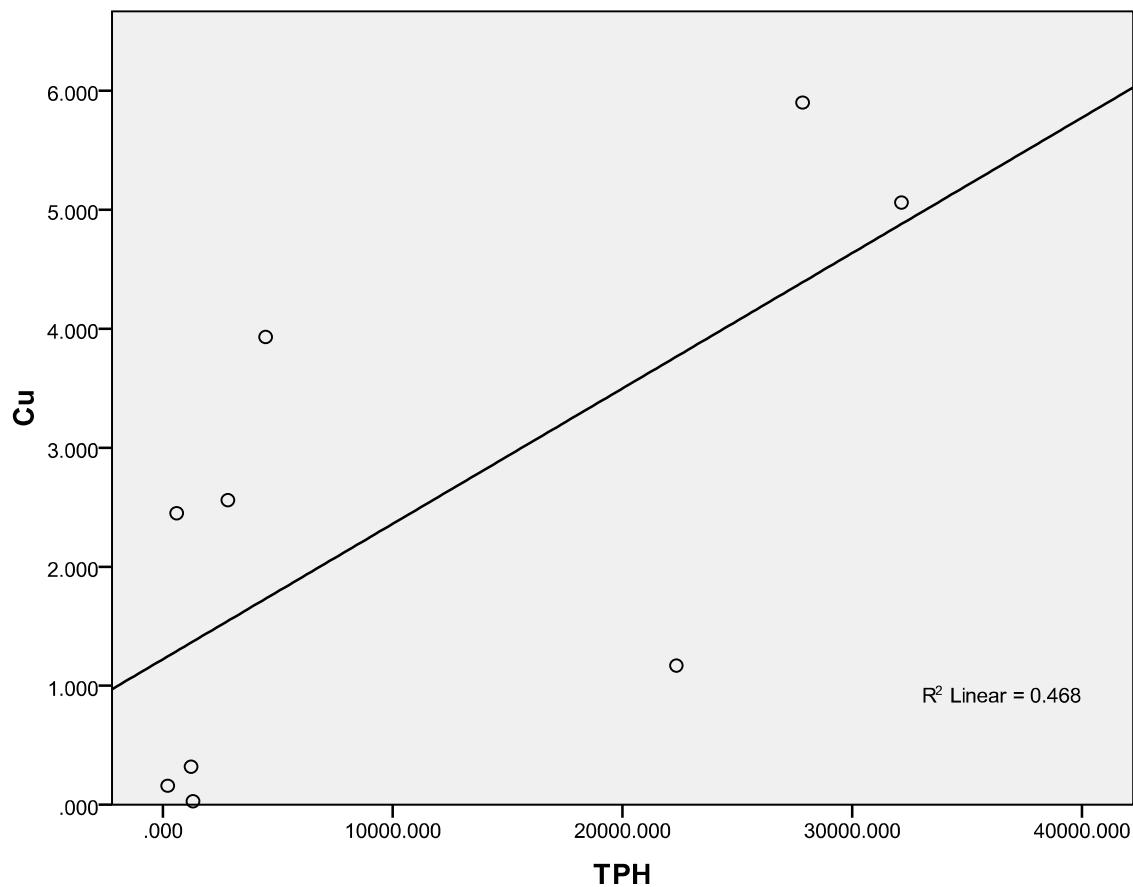


FIGURE 4.18 Regression plot between Total Petroleum Hydrocarbons and copper.

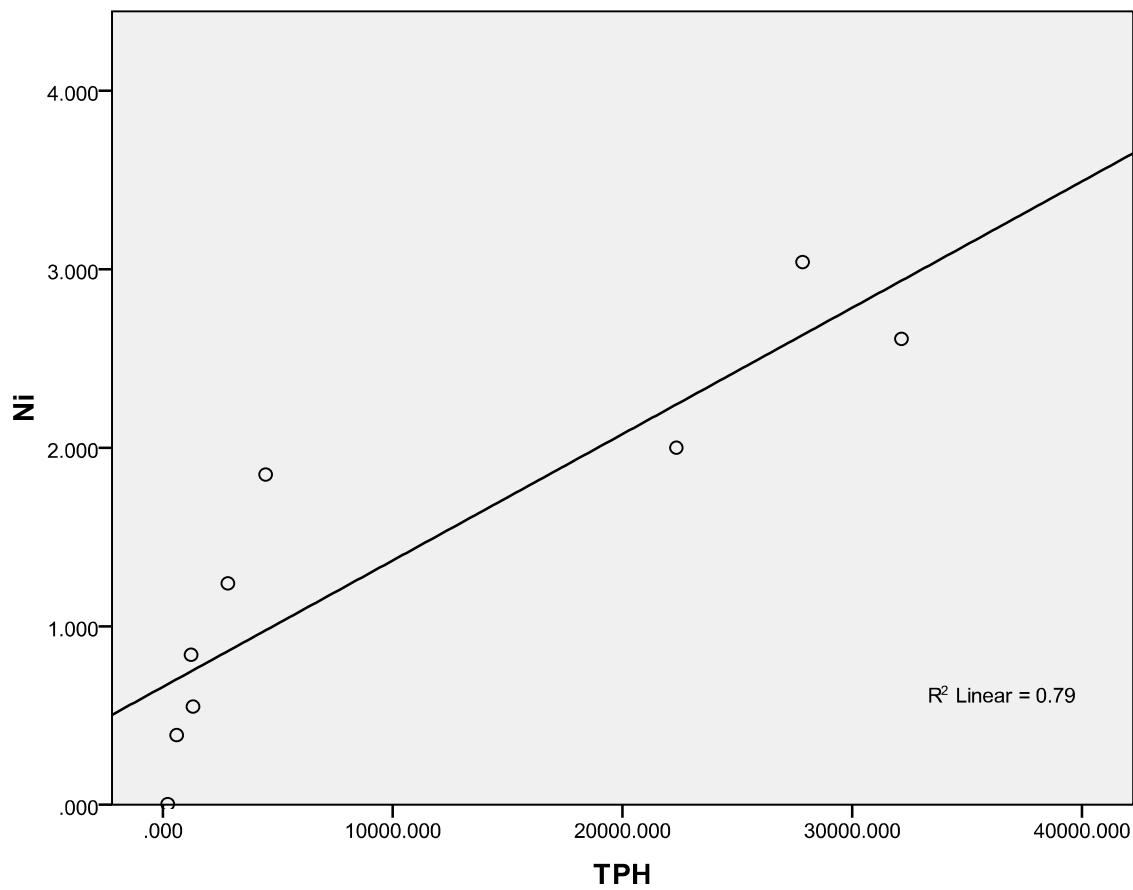


FIGURE 4.19 Regression plot between Total Petroleum Hydrocarbon with Nickel

CHAPTER FIVE: DISCUSSION, CONCLUSION AND RECOMMENDATION

5.1 DISCUSSION

From table 4.1 Soil pH is a measure of the soil acidity or soil alkalinity. An acid solution has a pH value less than 7. While a basic solution always has a pH larger than 5.6, a red solution, (Arnold Finck, Kiel 1976: Pflanzenernährung in Stichworten, p.80) it was observed that at sample location 1 and 2 pH recorded an average of 4.10 and at control location 3, recorded 5.72 making the soil acidic.

Total petroleum hydrocarbon (TPH) is a term used to describe a broad family of several hundred chemical compounds that originally come from crude oil. Thus, it is a mixture of chemicals. The health effects associated with Total petroleum hydrocarbon (TPH) depends on various factors such as; period of exposure, type and quantity of chemicals ingested. Some can affect the central nervous system, while others can cause fatigue, headache, nausea, drowsiness or even death in some cases. The concentration of the total petroleum hydrocarbon (TPH) at sample location 1 and control recorded low at an average of 202.1 and sample location 2 recorded very high with a value of 32142.00. Comparing with the control value shows that there is very high increase in Total petroleum hydrocarbon.

Nitrate is a natural material in soils, adequate supply of nitrate is necessary for good plant growth. Probably more than 90 percent of the nitrogen absorbed by plants is in the

nitrate form (Department of Agronomy). Nitrate recorded 3.8 on sample location 1 and 2.5 on sample location 2, while the control sample recorded 7.3. Nitrate was lower in concentration compared with the control sample.

Phosphate had a lower value of 9.3 at sample location 1 and a higher value of 148.0 in sample location 2, and control location recorded 8.8. phosphate was higher when compared to control samples.

Sulphate soils are the common name given to soils containing iron sulphides. Sample location 1 recorded 1.0 and sample location 2 recorded 3.0, while the control had a value of 5, making sulphate lower in concentration compared with the control sample.

Zinc present in sample location 1 recorded 15.42 and in location 2 recorded 19.2, while the control location recorded a lower value of 9.61. And when compared to EGASPIN (Environmental standard and guideline for the petroleum industry in Nigeria) it fell below the Limit.

Cadmium present in sample location 1 recorded 0.28 and in location 2 recorded 0.15, while the control location recorded a lower value of 0.09. And when compared to EGASPIN (Environmental standard and guideline for the petroleum industry in Nigeria) it fell below the Limit.

Chromium present in sample location 1 recorded 07.62 and in location 2 recorded 2.54, while the control location recorded a lower value of 0.0030. And when compared to

EGASPIN (Environmental standard and guideline for the petroleum industry in Nigeria) it fell below the Limit.

Cobalt present in sample location 1 recorded 0.89 and in location 2 recorded 0.41, while the control location recorded a lower value of 0.0010. And when compared to EGASPIN (Environmental standard and guideline for the petroleum industry in Nigeria) it fell below the Limit.

Copper present in sample location 1 recorded 3.93 and in location 2 recorded 5.9, while the control location recorded a lower value of 0.32. And when compared to EGASPIN (Environmental standard and guideline for the petroleum industry in Nigeria) it fell below the Limit.

Lead present in sample location 1 recorded 17.6 and in location 2 recorded 6.57, while the control location recorded a lower value of 8.93. And when compared to EGASPIN (Environmental standard and guideline for the petroleum industry in Nigeria) it fell below the Limit.

Nickel present in sample location 1 recorded 1.85 and in location 2 recorded 3.04, while the control location recorded a lower value of 0.84. And when compared to EGASPIN (Environmental standard and guideline for the petroleum industry in Nigeria) it fell below the Limit.

Parameters like magnesium, iron and cadmium weren't compared with standard due to the irregularity of guidelines for heavy metals on soil; this however was compared with

the control samples. It was noticed that for Magnesium, the concentration was highest in the first sample location recording a value of 60.35 while other sample locations had lower concentrations when compared with the control.

Iron recorded highest value 4668.6 in sample location 1 and sample location 2 recorded a value of 2626.4 and when compared with the control sample was found higher than the control making iron present in the soil.

From table 4.2 The origin of these heavy metals in the polluting oil soil was corroborated by there being significant positive correlation with TPH (Total Petroleum Hydrocarbon) correlated positively at $p<0.01$ with phosphate ($r=0.992$), Zn ($r=0.848$), Ni ($r=0.889$) and correlated positively at $p<0.05$ with Cu ($r=0.778$).

5.2 CONCLUSION

It could be seen from the above that the externalities of oil extraction have resulted in profound adverse impacts on traditional lifestyles and livelihood patterns in the Ogoni community where oil exploration and exploitation had taken place for the past years. This paper has discussed the likely effect of post- spills on the soil of the oil bearing Niger Delta community and the environmental problems that could still persist from the remediation. Examples are resource degradation, pollution, etc. And analysis is carried out, to be able to find out a solution that can, to an extent be on a tolerable level.

The oil companies and the government should show more commitment to the use of abatement procedures and environmentally sound and cleaner technologies for oil exploration and exploitation.

5.3 RECOMMENDATIONS.

- (1) All laws concerning oil, gas and land-use that exclude indigenous peoples from participation in the control and use of their resources be abrogated or amended. And there is need for proper monitoring.
- (2) A multi-stakeholder approach to oil exploration and exploitation should be put in place involving the triad of government, oil companies and host communities. The multi-stakeholder mechanism should address issues of biodiversity conservation and regeneration.
- (3) Oil and gas matters which are currently put on the exclusive legislative list should be removed and put on concurrent list to enhance partnership and collaborative decision making involving the oil companies, government and host communities. This will provide more choices for the people.
- (4) The government of Nigeria should muster the political will to exact stricter respect for environmental laws and regulations by oil companies and a penalty plan established that require oil companies whose activities cause excessive pollution or are ill-equipped, to forfeit their licenses.

- (5) An insurance fund against oil pollution be established by the government and the oil companies. In this fund, all the socio-economic costs resulting from oil pollution, can be charged and insured against.
- (6) A rapid oil spill response mechanism be put in place by the government and oil companies which must be committed to responding to communities in distress due to oil spills
- (7) The government should require oil companies to provide all the necessary social infrastructures before the commencement of oil exploitation so that their operations will not impact negatively on the immediate local population.
- (8) The current compensation regime in Nigeria has to be reviewed for it to be fair and adequate to meet the emergency needs and concerns of those affected by pollution.

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APPENDIX 1

Variables Entered/Removed^b

Model	Variables Entered	Variables Removed	Method
1	TPH ^a		.Enter

a. All requested variables entered.

b. Dependent Variable: Phosphate

Model Summary^b

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.992 ^a	.984	.982	7.512795

a. Predictors: (Constant), TPH

b. Dependent Variable: Phosphate

ANOVA^b

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	24207.468	1	24207.468	428.890	^a .000
	Residual	395.095	7	56.442		
	Total	24602.562	8			

a. Predictors: (Constant), TPH

b. Dependent Variable: Phosphate

Coefficients^a

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
1	(Constant)	2.277	3.261	.698	^a .508
	TPH	.004	.000		

a. Dependent Variable: Phosphate

Residuals Statistics^a

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	3.12394	136.94511	45.54444	55.008485	9
Std. Predicted Value	-.771	1.662	.000	1.000	9
Standard Error of Predicted Value	2.771	5.074	3.470	.751	9
Adjusted Predicted Value	1.83168	127.67050	44.87643	53.953873	9
Residual	-9.697414	11.054886	.000000	7.027576	9
Std. Residual	-1.291	1.471	.000	.935	9
Stud. Residual	-1.458	1.995	.036	1.113	9
Deleted Residual	-12.366758	20.329502	.668014	10.147480	9
Stud. Deleted Residual	-1.617	2.813	.097	1.335	9
Mahal. Distance	.199	2.761	.889	.839	9
Cook's Distance	.023	1.670	.263	.534	9
Centered Leverage Value	.025	.345	.111	.105	9

a. Dependent Variable: Phosphate

APPENDIX 2

Variables Entered/Removed^b

Model	Variables Entered	Variables Removed	Method
1	TPH ^a		. Enter

a. All requested variables entered.

b. Dependent Variable: Zn

Model Summary^b

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.848 ^a	.719	.678	3.634255

a. Predictors: (Constant), TPH

b. Dependent Variable: Zn

ANOVA^b

Model	Sum of Squares	df	Mean Square	F	Sig.
1	Regression	236.025	1	236.025	17.870
	Residual	92.455	7	13.208	
	Total	328.480	8		

a. Predictors: (Constant), TPH

b. Dependent Variable: Zn

Coefficients^a

Model	Unstandardized Coefficients			t	Sig.
	B	Std. Error	Beta		
1	(Constant)	7.077	1.578	4.486	.003
	TPH	.000	.000		

a. Dependent Variable: Zn

Residuals Statistics^a

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	7.16018	20.37403	11.34889	5.431681	9
Std. Predicted Value	-.771	1.662	.000	1.000	9
Standard Error of Predicted Value	1.340	2.455	1.679	.363	9
Adjusted Predicted Value	7.13903	21.51000	11.45921	5.581765	9
Residual	-4.443345	6.496218	.000000	3.399534	9
Std. Residual	-1.223	1.787	.000	.935	9
Stud. Residual	-1.350	1.923	-.013	1.028	9
Deleted Residual	-5.417188	7.519020	-.110323	4.118566	9
Stud. Deleted Residual	-1.453	2.592	.041	1.213	9
Mahal. Distance	.199	2.761	.889	.839	9
Cook's Distance	.008	.291	.102	.100	9
Centered Leverage Value	.025	.345	.111	.105	9

a. Dependent Variable: Zn

APPENDIX 3

Variables Entered/Removed^b

Model	Variables Entered	Variables Removed	Method
1	TPH ^a		.Enter

a. All requested variables entered.

b. Dependent Variable: Cu

Model Summary^b

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.684 ^a	.468	.391	1.703929

a. Predictors: (Constant), TPH

b. Dependent Variable: Cu

ANOVA^b

Model	Sum of Squares	df	Mean Square	F	Sig.
1 Regression	17.845	1	17.845	6.146	.042 ^a
Residual	20.324	7	2.903		
Total	38.168	8			

a. Predictors: (Constant), TPH

b. Dependent Variable: Cu

Coefficients^a

Model	Unstandardized Coefficients			Standardized Coefficients	t	Sig.
	B	Std. Error	Beta			
1 (Constant)	1.223	.740			1.653	.142
	.000	.000	.684		2.479	.042

a. Dependent Variable: Cu

Residuals Statistics^a

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	1.24603	4.87937	2.39778	1.493517	9
Std. Predicted Value	-.771	1.662	.000	1.000	9
Standard Error of Predicted Value	.628	1.151	.787	.170	9
Adjusted Predicted Value	1.03686	4.72782	2.37140	1.470069	9
Residual	-2.594895	2.199040	.000000	1.593879	9
Std. Residual	-1.523	1.291	.000	.935	9
Stud. Residual	-1.720	1.388	.006	1.047	9
Deleted Residual	-3.309174	2.545269	.026383	2.002215	9
Stud. Deleted Residual	-2.095	1.510	-.019	1.140	9
Mahal. Distance	.199	2.761	.889	.839	9
Cook's Distance	.009	.407	.127	.136	9
Centered Leverage Value	.025	.345	.111	.105	9

a. Dependent Variable: Cu

APPENDIX 4

Variables Entered/Removed^b

Model	Variables Entered	Variables Removed	Method
1	TPH ^a		.Enter

a. All requested variables entered.

b. Dependent Variable: Ni

Model Summary^b

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.889 ^a	.790	.760	.512238

a. Predictors: (Constant), TPH

b. Dependent Variable: Ni

ANOVA^b

Model	Sum of Squares	df	Mean Square	F	Sig.
1 Regression	6.909	1	6.909	26.333	.001 ^a
Residual	1.837	7	.262		
Total	8.746	8			

a. Predictors: (Constant), TPH

b. Dependent Variable: Ni

Coefficients^a

Model	Unstandardized Coefficients			t	Sig.
	B	Std. Error	Beta		
1 (Constant)	.661	.222		2.971	.021
	7.078E-5	.000	.889	5.132	.001

Coefficients^a

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
1 (Constant)	.661	.222		2.971	.021
TPH	7.078E-5	.000	.889	5.132	.001

a. Dependent Variable: Ni

Residuals Statistics^a

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	.67488	2.93573	1.39156	.929345	9
Std. Predicted Value	-.771	1.662	.000	1.000	9
Standard Error of Predicted Value	.189	.346	.237	.051	9
Adjusted Predicted Value	.72765	3.20901	1.41084	.960179	9
Residual	-.670879	.873373	.000000	.479155	9
Std. Residual	-1.310	1.705	.000	.935	9
Stud. Residual	-1.451	1.834	-.016	1.048	9
Deleted Residual	-.823617	1.010882	-.019287	.606820	9
Stud. Deleted Residual	-1.607	2.357	.032	1.187	9
Mahal. Distance	.199	2.761	.889	.839	9
Cook's Distance	.004	.312	.136	.124	9
Centered Leverage Value	.025	.345	.111	.105	9

a. Dependent Variable: Ni

APPENDIX 5

SPATIAL VARIANCE EQUALITY

Anova: Single Factor

SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>
Column 1	45	39301.77	873.3728	17003880
Column 2	45	90	2	0.681818

ANOVA

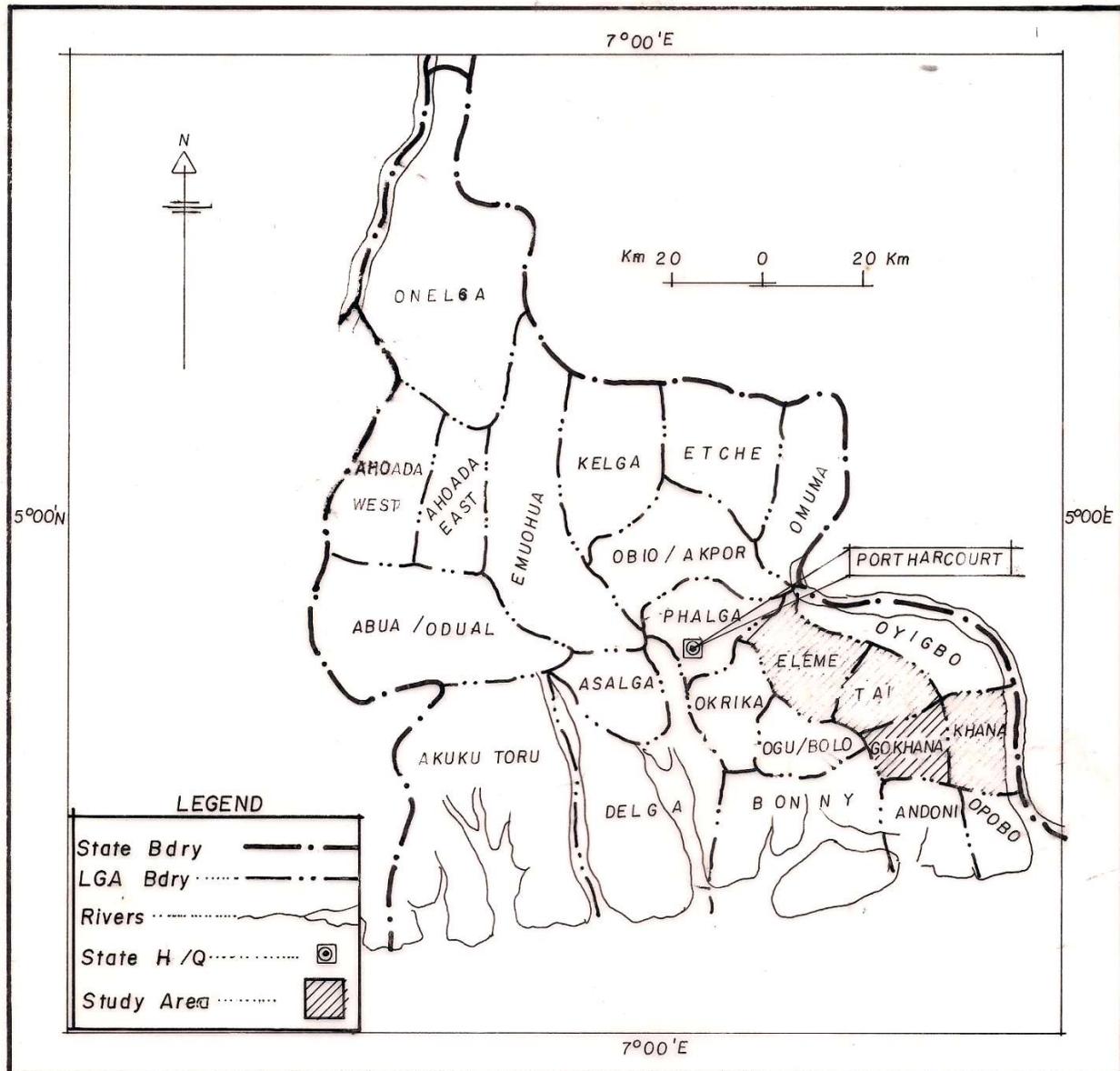
<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	17084036	1	17084036	2.009428	0.159855	3.949321
Within Groups	7.48E+08	88	8501940			
Total	7.65E+08	89				

APPENDIX 6

S/N	SUBSTANCE	SOIL/SEDIMENT (mg/kg dry material)	
		Target value	Intervention value
1.	Cadmium	0.8	12
2	Chromium	100	380
3	Cobalt	20	240
4	Copper	36	190
5	Mercury	0.3	10
6	Lead	85	530
7	Nickel	35	210
8	Zinc	140	720
9	Mineral oil	50	5,000

Environmental Guidelines and standards for the petroleum industry in Nigeria (EGASPIN). Revised Edition 2002. Pg. 280. Table VIII-F1

APPENDIX 7



Map of Rivers State Showing the Local Govt Areas, the study area, in OGONI Land ; Gokhana, Khana, Eleme & Tai

APPENDIX 8

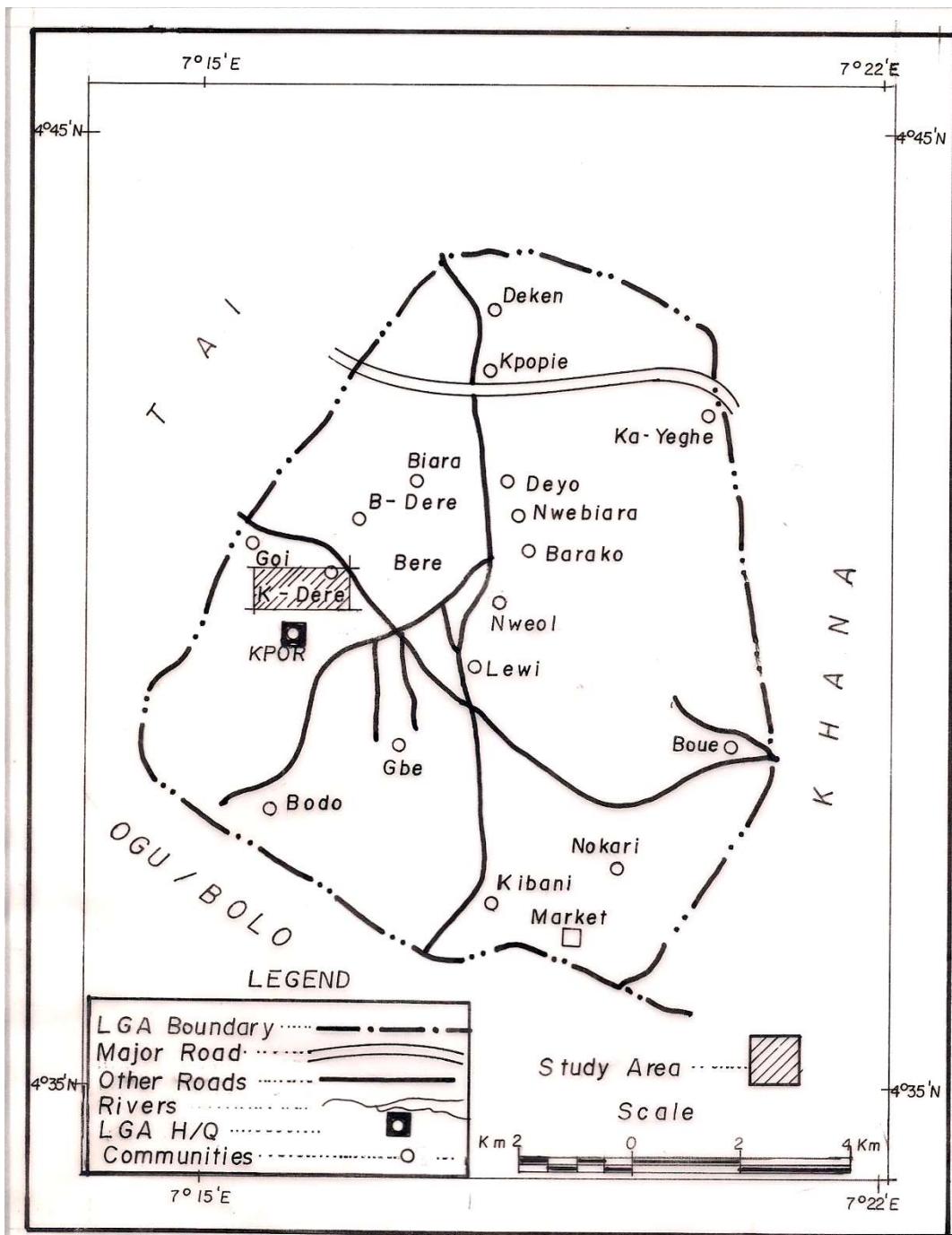


Fig 2; Sample Location Map at K-DERE Community in
GOKHANA Local Government Area of Rivers State



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