COMPARATIVE ANALYSIS OF SOIL QUALITY IN ABAM AMA AND ABULOMA RIVERS STATE

BY

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CERTIFICATION

This [illegible] certify that this work "**COMPARATIVE ANALYSIS OF SOIL QUALITY IN ABUL [illegible]A AND ABAM AMA, RIVERS STATE**" was carried out by **YOUNG, SILVERLINE ADOKI** with Registration Number **20085659949** in partial fulfilment of the requirements for the Award of Master of Technology (M.Tech.) degree in the Department of Environmental Technology, School of Environmental Sciences, Federal University of Technology, Owerri (FUTO)

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DECLARATION

I, YOUNG, SILVERLINE ADOKI (FUTO/20085659949) hereby declare that this thesis is my original work carried out and written by me, it has not been printed, published or submitted as research work in any form in whole or in part for the award of any other diploma or degree of this University, Research Institution or any other Institution of higher learning in Nigeria or Abroad.

_______________________________ __________________

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DEDICATION

To Jehovah – The Almighty God

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ABSTRACT

This study involved proximate analyses of eight soil samples taken from playground, open space, relic farmlands and road within an average distance of 500m from each other in two communities (Abam Ama – a neighbouring community of Port Harcourt Refinery experiencing legacy emissions and Abuloma a marine/industrial community in the Trans Amadi Industrial layout of Port Harcourt Local Government Area of Rivers State. The study examines the spatial variation of soil characteristics identifying if levels are distributed evenly by looking at indicators of change, i.e. pH or to identify if soil leaching has occurred in relation to the concentration of the following heavy metals copper (Cu), zinc (Zn), lead (Pb), and manganese (Mn) as well as the concentration of Total Petroleum Hydrocarbon (TPH). In addition accessing the impact of past industrial activity on the soil quality. Methods used included systematic sampling to collect a total of 8 samples from four transects 0-15cm.. Samples were analyzed in the laboratory for concentrations of Cu, Mn, As, Al, Zn and Pb using acid digestion followed by an ICP-OES Varian 725-ES.The study indicates the soil pH to be acidic in nature affecting mobilization of metals and their ability to leach through the soil profile. There is spatial variation of heavy metal concentrations and contamination between Abam Ama and Abuloma but not much within each community The test of variance of heavy metals, and other edaphic variables measured such as CEC and TPH at the various sampling locations in Abam Ama (Okrika) and Abuloma (Port Harcourt) using the analysis of variance (ANOVA) revealed that the parameters differed significantly in their means at $P<0.05$ [F (cal 4.820)> F (Crit = 3.89)]. The study concludes metal contamination and soil leaching varies spatially due to the following soil characteristics; pH, geology, habitat, and anthropogenic influences from industry. Children are more at risk to heavy metal impact that adults and the people of Abuloma are more predisposed to pollution than Abam Ama because of the concentration industrial activities.

***Keywords**: Soil quality; Heavy metals; Pollution; Hydrocarbon; Abam Ama; Abuloma.*

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Over the last three decades there has been increasing global concern over the public health impacts attributed to environmental pollution, in particular, the global burden of disease. The World Health Organization (WHO) estimates that about a quarter of the diseases facing mankind today occur due to prolonged exposure to environmental pollution. Most of these environment-related diseases are however not easily detected and may be acquired during childhood and manifested later in adulthood.

Improper management of waste (solid, liquid & hazardous) is one of the main causes of environmental pollution and degradation in many cities, especially in developing countries. Many of these cities lack solid waste regulations and proper disposal facilities, including for harmful waste. Such waste may be infectious, toxic or radioactive. In recent times, spills related to the Hydrocarbon industry such as crude oil and refined oil spills (via land transportation, vandalization of product pipeline etc.), grease, spent oil etc. have been finger-printed especially in the Niger Delta Region of Nigeria.

Until recently, the impacts of soil pollution on the health have had a much lower profile. In addition, the science involved is complex (Science for Environment Policy, 2012). Researchers are making good progress with developing our understanding of many soil-related issues, such as soil sealing, erosion and contamination, but the impacts of soil contamination on our health are not as well documented.

Of particular concern is citizens' long- *term, low-level exposure to a range of soil contaminants, including both current and legacy (historical) emissions. Cases of populations suffering from high levels of soil contamination in specific locations around the world have been studied extensively by epidemiologists and toxicologists to understand the health impacts of soil-borne chemicals in the environment. In these cases, the cause and effect are often relatively straightforward to determine.*

Soil is a complex amalgam, a non-renewable natural resource because it cannot be re-created except within the context of geological timescales. It can be simply defined as the unconsolidated mineral or organic material on the immediate surface of the Earth that serves as a natural medium for the growth of land plants (Alloway, 1994). Other definitions state it to be a reactor, transformer and integrator of material and energy from other natural resources (solar radiation, atmosphere, surface and subsurface waters, biological resources), a medium for biomass production; storage of water, nutrients and heat, natural filter and a medium of past and present human activities (Nortcliff 2002, Schaetzl & Anderson 2005,Blum 2005). It is a basic component of ecosystems and is one of the most vulnerable to contamination and degradation through accidental or deliberate mismanagement (Herbert et al, 1995).

There is increasing awareness that metals present in soil may have negative consequences on human health and on the environment, demonstrated by the many researchers (e.g Lanphear & Roughmann, 1997; Mielke & Reagan, 1998;Berglund et al., 2000; Mielke et al., 2005; Selinus et al., 2005). And a large proportion of the metals present in soil originate from diffuse emission sources such as long- and short-range atmospheric deposition. This is especially apparent in urban soil, where there are more diffuse emission sources, for example traffic and building *material, than in rural areas, resulting in short-range atmospheric deposition and a more general increase in metal contents (Paterson et al., 1996; Filippelli et al., 2005).*

Since metals are largely immobile in the soil system, an accumulation occurs over time which may result in levels that are harmful to humans upon both acute and chronic exposure (Thornton, 1991; Brinkmann, 1994; Sheppard, 1998). Because of the diffuse emission in urban areas and the accumulation of soil metals with time, even residential areas located away from point pollution sources may have elevated soil metal contents. Most children are exposed to metals present in soil because of their hand-to- mouth behaviour, which puts them in more frequent contact with soil than most adults.

Heavy metals and persistent organic chemicals are of particular concern. Human activity introduces heavy metals (such as cadmium, arsenic and mercury) to the soils through mining, smelting, industry, agriculture and burning fossil fuels. The disposal of materials containing heavy metals – a long list which includes paint, electronic waste, and sewage – also contributes to the burden of heavy metal contamination. Organic chemicals are also part of the industrial legacy, and many are still widely used today. Complex mixtures of these chemicals in the environment and in our bodies pose major challenges to toxicologists trying to understand the health impacts of these widespread substances.

In the last fifty-five years, the Niger Delta Region has experienced increased activities in the area of oil exploration and exploitation; refining and products marketing operations. While the same activities have generated immense financial benefit for the country, as a whole, it has created health and environmental hazards to the host communities domiciled in the Niger-Delta Region. The operations of the oil industries have introduced pollutants as liquid discharges and oil spills *into the air, land, and water components of the environment (Omajemite, 2008). The whole process of obtaining fuel mineral; from exploration, extraction, processing and transportation as well as storage and consumption generate one form of pollution or the other. For example, during exploration, drill cutting, drilling mud and fluids are used for stimulating production. During the transportation and marketing of crude oil, damage to oil pipeline and accident involving road trucks and tankers generate oil spill and hydrocarbon emission. This have a far more reaching effect on the environment (FEPA, 2001).*

The entire process of oil extraction negatively affects the environment basically through pollution which invariably leads to other kinds of problems (Aghalino, 2000). Ellis (1994) stated the crude oil is so dangerous that when the oil touches the leaf of food crops or whatever economic tree in the area, the plants dries off immediately. This destructive effect of petroleum on plants invariably leads to poor agricultural yield in the regions. The extinction of biodiversity, e.g. Flora and Fauna, destruction and contamination of soil, and the much obvious air/atmospheric pollution in the Niger delta has not only deteriorated the environment, but has also brought hopelessness to the inhabitants of the land.

1.2 Statement of the Problem

Contamination of soil by oil spills is a wide spread environmental problem that often requires cleaning up of the contaminated sites. These petroleum hydrocarbons adversely affect the germination and growth of plants in soils (Oyem and Oyem, 2013). Oil spills affect plants by creating conditions which make essential nutrients like nitrogen and oxygen needed for plant *growth unavailable to them (Adam et al., 2002).Oil spills have degraded most agricultural lands in the State and have turned hitherto productive areas into wastelands. With increasing soil infertility due to the destruction of soil micro-organisms, and dwindling agricultural productivity, farmers have been forced to abandon their land, to seek non-existent alternative means of livelihood.*

Many authors have reported a lower rate of germination in petroleum or its derivatives contaminated soil (Adam et al., 2002; Vavrek and Campbell, 2002; Achuba, 2006; Smith et al., 2006; Korade and Fulekar, 2009; Ogbo, 2009). Petroleum hydrocarbons may form a film on the seed, preventing the entry of oxygen and water (Adam et al., 2002) and toxic hydrocarbon molecules could inhibit the activities of amylase and starch phosphorylase and thereby affecting the assimilation of starch (Achuba, 2006). Henner et al. (1999) reported that petroleum hydrocarbons consisting of small molecules and those that are water soluble are more phytotoxic for the germination.

On its effect on human, soil can enter our bodies via three main routes: eating, inhalation and through the skin. Eating soil (geophagia) is a surprisingly widespread practice. Children under three, in particular, are very likely to eat soil while playing outdoors. As they are considered particularly sensitive to contaminants, young children are thought to be at highest risk from contaminated soils (for example, children absorb lead via their digestive system five times more efficiently than adults). Accidental ingestion may occur in adults (for example, by eating vegetables with some soil still attached). It is commonly believed that direct ingestion is the most important pathway for human exposure to soil contamination, although other specific pathways have some importance in certain situations. When consumed, some chemicals are absorbed *through the lining of the mouth, while others are swallowed and move into the digestive system. From here, they may be absorbed into the body and transported to the liver.Once in the liver, some chemicals are largely returned to the digestive system via bile, but others will enter the bloodstream. Some chemicals are broken down to a certain extent in the liver before they reach the blood. Where chemicals are not absorbed, and remain in the gut, they generally do not cause an adverse response, unless they have some direct toxicity to the gut lining.*

Working with soil (for example, in agriculture) releases particles into the air that may be inhaled by workers and others nearby. Very small particles may lodge in the lungs, and there is a chance that contaminants may be absorbed into the bloodstream. Compared to ingestion, this is a far less significant source of exposure, but may be relevant to those exposed repeatedly over a long time period.

*Skin contact Absorption through the skin tends to favour more volatile, organic compounds. This is less of a problem for heavy metals, although some specific forms Cr (VI), the more toxic form of chromium, or inorganic mercury) can cause skin contact problems. Absorption of a chemical thr*ough the skin is known as 'dermal absorption', or sometimes 'cutaneous' or 'transcutaneous absorption'.

Indirect contact Soil contaminants may move from soils into ground or surface water, leading to contaminated drinking water. They may also be taken up by plants which are subsequently consumed, either by humans or by agricultural livestock, causing contaminants to enter the human food chain. Some of these effects may be quite significant, as in the case of dioxins accumulating up the food chain, or large quantities of cadmium in crops grown in contaminated soils. High levels of arsenic in drinking water supplies are often another significant indirect result of soil contamination. Arsenic may also be naturally present in groundwater.

A contaminant becomes toxic in the human body once the body's own detoxification systems become overloaded. At this point, the body starts to be exposed to excess amounts either of the chemical itself or of a metabolite produced when the body's normal metabolic pathways (the means of processing the toxic compound) are saturated.

If a chemical accumulates in tissues, reaching critical toxicity may be an event that results from long-term accumulation. Factors that are relevant in this case are the body's rate of elimination (by metabolism or excretion), and the overall 'body burden' – the quantity of chemicals stored in body tissues (Environment Agency, 2009). Reliable data from human populations exposed to known levels of chemicals are not common, with the exception of human pharmaceuticals. For the majority of chemical contaminants, levels likely to pose risks to human health are estimated from toxicology studies on laboratory animals, and models.

The assessment of soil quality and comparing with communities within immediate and remote distances become an important part of environmental resource studies, planning and management. It is gaining significant importance due to intense urbanization, industrialization and agricultural activities that are increasing the risk of contamination of soil and water. Soil quality monitoring is important for the protection of public health agriculture. The knowledge of the state of environment vis-à-vis the soil quality is vital for sustainable development and environment and in addressing the problems highlighted above there is the need to ask the following questions:

i. What are the potential pollution sources in the area?
ii. What are the major soil pollutants in the study area?
iii. Who are likely at greater risk to the pollution threats in the study area?
iv. Is there a spatial variation of soil quality in the area?

1.3 Aim and Objectives of the study

The aim of this research therefore, is to investigate the spatial variation of soil characteristics and do a comparative analysis of soil in Abuloma Community (Marine/Industrial settlement in the Port Harcourt City Local Government Area) and Abam Ama Community (a semi-Urban Community bordering the Port Harcourt Refinery Company in Okrika Local Government Area). The aim is guided by the following objectives:

i. To examine the spatial variation of soil characteristics, to identify if levels are distributed evenly across sampling locations in both study areas by looking at indicators of change.

ii. To identify levels of the heavy metals concentrations; copper (Cu), zinc (Zn), lead (Pb), Iron (Fe), and manganese (Mn) in the topsoil (15cm) in order to assess the impact of industrial activity on their quality. To see if the site is identified as contaminated on the basis of existing FEPA/NESREA Soil Quality Guideline Values

iii. To conduct Gradation test to determine soil grain sizes and relative permeability and possible influence in the transmission of "contaminated" water to the groundwater table

iv. To identify the major pollution sources including legacy sources in the area

v. To find out the predominant soil-borne diseases and their relatedness to the quality of the soil in the area.

vi. To discuss the findings in relation to international and nationally established quality standards.

1.4 Hypotheses

The following hypotheses are therefore formulated for this study:

i. *There are no variation in soil heavy metals between Abuloma and Abam Ama Communities*

ii. *The soil in the area is not under threat of Soil pollution from industrial related activities*

1.5 Significance/Justification of the study

The significance of this study is hinged on the facts in Rivers State oil pollution has added to pollution from domestic, industrial and hospital wastes. The study will help unravel the quality of soil in the study area. The comparative study will expose the magnitude of impacts of these industries in the study areas. The possible consequences of these activities on agricultural soils and farming and the need for remediation works will be emphasized if the regulatory agencies of government and oil companies are sensitized.

1.6 Scope of Study (Delimitations)

The study is limited to Abuloma Community in Port Harcourt Local Government Area and Abam Ama in Okrika Local Government Area of Rivers State. It involved the identification through fieldwork/observation of various playground, open spaces and farmlands and the collection of soil samples for laboratory analyses to determine the quality status with reference to National and International standards

CHAPTER TWO

LITERATURE REVIEW/CONCEPTUAL AND INSTITUTIONAL FRAMEWORKS

2.1 Soil contamination

Soil pollution embraces perilous garbage such as consumed catalysts, residues and sediments produced by clearing sediments out from tanks keeping materials or mud taken from refining sewage that might be dumped in lands or certain places. This phenomenon gradually led into soil pollution and other probable environmental hazardous (Page et al., 1999). Solid redundancies produced in refineries usually contain active slime, consuming catalysts, waste slime, refined materials and different sediments. Huge amount of produced residues are collected within refineries and dumped in landfills. The volume of solid redundancies (Total Suspended Solids) TSS depends on the magnitude of refineries and the amount of exactness during keeping and repairing procedures. The ratio of solid surplus materials is built upon the intensity complex of the wastes, refining system and the construction of the productive unit. The characteristics of these materials are highly influenced by the combination of crude materials and refining procedures. The properties of such materials and the geographical and climatic conditions should be reckoned in order to landfill the redundancies. Since land filling causes environmental problems, this method is rarely practiced in comparison to other methods of disposing solid redundancies. For the sake of inappropriate refining, floating solid particles in wastes are able to fill soil's pores after settlement and this result in stopping soil's breathing and destroying its *physical and chemical properties.*

2.1.1 Effects of organic contaminants on soil biota and quality

Either environmental contaminations, from diffuse or point sources, may compromise the ability of ecosystems to provide society with those goods and services that we require. Contamination is also linked to other widely recognized anthropogenic threats to sustainable functioning of our planet, such as the loss of biodiversity. As many soil properties and processes are conferred by soil biota, it is currently widely agreed that biological characteristics should be taken into account when evaluating the quality, or health, of soil (Ritz et al., 2009).

Microbial communities can respond to disturbances, such as contamination, in many different ways; any of these responses may result in perceived stability or the continuation of essential soil functions (Allison and Martiny, 2008). The key species may show resistance to perturbation, meaning that the pollutants have no negative (or positive) effect on them. If the initial reaction is negative but the key species are able to regain their numbers and functionality, the community is said to be resilient. If the key species are irreversibly affected but are replaced by other indigenous species that are able to perform the same task under the new conditions, we see redundancy. Only if all these backup strategies fail will the deleterious effects of contamination on soil functions be observed. Some specific processes, such as the degradation of recalcitrant chlorinated compounds or nitrogen fixation in symbiosis with leguminous plants, can only be performed by a few specialized microbial genera. If these key populations are compromised, these soil functions may be completely lost. However, for the majority of general soil processes, there is functional redundancy, with a plethora of diverse microorganisms able to perform the *same actions under slightly differing Conditions (Prosser, 2012). For example, the decomposition of plant material is performed by both soil bacteria and fungi, with the former dominating in neutral or alkaline soils and the latter dominating under acidic conditions (Rousk et al., 2010). The perceived ecological relevance of biodiversity lies in this ability of other species to take over a task if the original agent is disturbed or eliminated (insurance theory). Biodiversity, generally referred to as richness (i.e. number of different species) from the point of view of conservation, is thus assumed to ensure ecosystem stability (Griffiths and Philippot, 2012; Prosser, 2012). The microbial diversity of soil is vast: up to ten million species with a collective prokaryotic genome ten thousand times the size of the human genome have been found in a mere handful of dirt. In addition to rapid microbial mechanisms of genetic reorganization and 3.7 billion years of evolution, this diversity is predominantly produced and maintained in soil by spatial isolation of dispersed cells and small colonies (Carson et al., 2010; Fierer and Lennon, 2011). Although the majority of soil bacteria or archaea will never interact, even with their neighbouring cells just a few millimeters away (Or D et al., 2007and Prosser, 2012), such a wide biodiversity can be expected to convey a very high level of functional redundancy in microbially mediated soil processes.*

The true relevance of the natural soil microbial species richness, especially because many species are found in very low abundance, is still a highly disputed topic among microbial ecologists (Prosser, 2012). For example, a high richness does not seem to be linked to higher rates of general soil processes such as degradation of organic C. On the other hand, high diversity has been connected to more efficient degradation of hydrocarbons (Dell'Anno *et al., 2012) and a reduced persistence of invader species (van Elsas et al., 2007). In addition, a severe decrease in microbial diversity seems to be associated with an increased susceptibility of soil processes to* *further perturbation (Prosser, 2012). Soil contamination with inorganic or organic pollutants commonly reduces the diversity or evenness (even distribution of species) of soil bacteria (Griffiths and Philippot, 2012; Prosser, 2012). Generally, a combination of multiple stressors, such as different pollutants or contamination and drought, exerts especially high pressure on soil communities, and the combined negative effect may not be additive but rather synergistic (Højer et al., 2001). In the case of soil microbes, this general ecological principle does not seem to hold; prior stress has been associated with both an increase in sensitivity and an increase in community resistance or resilience. In the latter case, the explanation may lay either in similar physiological mechanisms of resistance to multiple stressors or in community adaptation through increased numbers of generally more resistant species. The production of persistent resting forms such as bacterial endospores under stressful conditions can result in increased resilience. Dormancy in general, meaning minimal metabolic activity associated with minimal interaction with the environment, can deliver the same advantages and seems to be a common survival strategy for soil bacteria (Fierer and Lennon, 2011).*

The apparent resistance of soil microbial communities to contaminants may not be caused by insensitivity of the exposed organisms but rather by the fact that the pollutants simply are not bio available in the specific environment to the organisms under observation on the time scale of the observation. This holds especially true for organic contaminants with high Kow values (Loibner et al., 2006). Aromatic and halogenated compounds introduced into soil in sludge tend to remain adsorbed in sludge solids such as organic material or fine inorganic particles (Clarke and Smith, 2011). If the compounds are released due to degradation of the sludge-derived organic material, pollutant molecules may further be adsorbed on or absorbed in more recalcitrant soil organic matter. Such sorption may be either reversible or irreversible, but in any case, the mobility of *low-concentration organic contaminants with poor aqueous solubility in soil is very restricted. As soil microorganisms are often located in micropores or inside aggregates, their spatial separation from pollutants can efficiently reduce their exposure.*

If an organic pollutant in soil is sufficiently bioavailable to exert toxic effects, it is generally also bioavailable to organisms able to degrade it. However, the opposite may not hold true because degradative bacteria often have specific mechanisms to improve access to and uptake of organic compounds. The evolutionary rationale for acquiring such mechanisms is that the bacteria degrading organic pollutants are often able to use these as sources of energy, C and N (Leuing et al., 2007). Because the degradation capacity thus provides a combined competitive advantage in the form of both protection and cell building blocks, microbes have evolved pathways to catabolise seemingly any organic compound (Robertson et al., 2007). Such organisms are also widely spread. Hydrocarbon degraders can be detected in any environment contaminated with crude or refined oil (Brassington et al., 2007). However, degraders of many emerging contaminants (Hernandez-Raquet, 2012) belong to bacterial taxa common in the soil environment (Janssen, 2006).

Horizontal transfer of the degradation genes from a degrader to another bacterial species, genus or even family further increases the capacity of the microbial community to cope with contamination (Griffiths and Philippot, 2012). On the other hand, some of the newer compounds, especially halogenated aromatic molecules, may be thermodynamically and biochemically so challenging to catabolise that optimal degradation pathways are still under evolutionary development (Copley et al., 2012). For such compounds, the degraders are not necessarily widely spread in nature yet. Moreover, the concentrations of such emerging contaminants in the *environment may not be sufficient to support the development or maintenance of specialized degrader communities, whereas more abundant and readily utilizable pollutants such as oil typically cause a rapid increase in the number of degraders (Mikkonen, 2012).*

2.1.2 Effect of municipal waste dumpsite on the soil

Municipal waste generation is increasing at the urban and developing cities around the globe. The high rates of urbanization and by extension industrialization of Rivers State especially the Greater Port Harcourt Region (covering Port Harcourt City LGA, Obio/Akpor LGA, Ikwerre LGA, Oyigbo LGA, Eleme LGA and Okrika LGA) has made the State and the listed LGAs one of the most densely populated in Nigeria; with an estimated growth rate of 3.4%. The Rivers State population increased from 5,198,716 in 2006 to about 6,214,664 in 2011 with the listed LGAs contributing more than 70% (FRN GAZETTE VOL 94 JAN 2007 & VOL 96 FEB. 2009). This rising population density has persistently caused large volumes of waste of various categories to be generated daily by the inhabitants. Ogbonna et al., (2007), reported that about 342,880 metric tons of solid waste are generated per year in the Port Harcourt Metropolis. They went further to extrapolate that with a base population of 653,183 in 1991 and the nationally adopted growth rate of 3.0 per cent for that era, about 1,393,880kg/day of waste is generated in the Metropolis with no environmentally safe landfills to cater for them.

Waste management in developing countries is usually equated with land disposal or sometimes, discharges into bodies of water (Cilinskis and Zaloksnis, 1996; Gobo et al., 2014), even though these methods of waste management are unscientific, cause nuisance to the public, and constitute pollution and health hazards. When waste is dumped on land, soil microorganisms, including fungi and bacteria, readily colonize them and cause degradation and transformation of the *degradable (organic) materials in them (Steinet al., 1990). They do this by using the waste constituents as nutrients, thereby detoxifying the waste materials as their digestive processes break down complex organic molecules into simpler and less toxic ones.*

Dumping of municipal waste on land is a common waste disposal method. Precipitation that infiltrates through the municipal refuse leaches the constituents from the decomposed waste mass and while moving down causes the subsurface soil to be contaminated by heavy metals, organic and inorganic solutes (Nolan, 2003). Due to the use of soil as a medium of disposal of municipal refuse and the use of incineration waste for civil works are becoming increasingly common, the definition of relevant soil biological, physical, and chemical indicators is indispensable to access their environmental compatibility (Perrodine et al., 2002). Many studies have assessed the ecotoxicological effects of leachates from municipal refuse dump on living organisms in soils belonging to eukaryotes (plants and animals) and prokaryotes (bacteria) plant growth inhibition (Hernandez et al., 1999). There are also potential beneficial effects from municipal refuse dump on agricultural and horticultural activities, soil that have been cropped for many years may be deficient in nutrients such as zinc, iron, copper as these metals are essential in soil fertility. However municipal waste could mitigate such deficiencies (Bruine et al., 2009).

2.1.2.1 Impact of municipal waste dumpsite on soil microorganisms

Waste is said to be hazardous if it is infectious, meaning containing viable microorganisms or their toxins which are known or suspected to cause disease in animal or human (Yakowitz, 1988). When waste is dumped on land, soil microorganisms including fungi and bacteria, readily colonize the waste carrying out the degradation and transformation of degradable (organic) materials in the waste. Microorganisms in waste dump use the waste constituents as nutrients, *thus detoxifying the materials as their digestive processes breakdown complex organic molecules into simpler less toxic molecules (Onuegbu, 2013). This metabolic activity can be attributed to their high growth rate, metabolism, and their ability to degrade a vast variety of naturally occurring organic materials.*

2.1.2.2 Effects soil contamination on agriculture

Plants germinate, develop and grow in soil medium where water, air and nutrient resources supply plants for healthy growth for productive and profitable agriculture. Frequent crude-oil spillage on agricultural soils, and the consequent fouling effect on all forms of life, renders the soil (especially the biologically active surface layer) toxic and unproductive. The oil reduces the soil's fertility such that most of the essential nutrients are no longer available for plant and crop *utilization (Abii and Nwosu, 2009). The enormity of toxicity by oil spillage on crop performance is exemplified in mangrove vegetation, which has been dying off in recent times (Henry and Heinke, 2005). Spilled crude-oil which is denser than water, reduces and restricts permeability: organic hydrocarbons which fill the soil pores expel water and air, thus depriving the plant roots the much needed water and air (Brian, 1977). Soil properties involved in soil-plant-water relationship are degradable and include texture, infiltration, hydraulic conductivity, moisture content, pH and density, which affect root and leaf development and plant growth and yield (Michael, 1978; CIGR, 1999; Michael and Ojha, 2006).*

Odugwu and Onianwa (1987) demonstrated the effect of pollution on germination, growth and nutrient uptake using pawpaw, and Amadi et al. (1996) demonstrated chronic effects on soil *properties and microflora in a rainforest system. Daniel-Kalio and Braide (2004) showed its effect on cultivated wetland areas of the Niger Delta. Other researchers employed maize, capsicum and lycopersicum and dayflower for observation of pollution effect (Anoliefo and Nwosu, 1994; Daniel-Kalio and Pepple, 2006).*

2.2 Heavy metal contamination

The term heavy metal refers to any metallic chemical element that has a relatively high density and is toxic or poisonous at low concentrations. Examples of heavy metals includes lead (Pb), cadmium (Cd), Iron (Fe), Zinc (Zn). Heavy metals are natural components of the earth's crust. *They cannot be degraded or destroyed. To a small extent, they enter our bodies via food, drinking water and air. As trace elements, some heavy metals are essential to maintain the metabolism of the human body. However, at a higher concentration they can lead to poisoning. Heavy metal poisoning could result from drinking water contamination (e.g. lead pipes), high ambient air concentration near emission sources or intake via the food chain.*

2.2.1 Iron

Iron is believed to be the tenth most abundant element in the universe. It is also the most abundant (by mass, 34.6%) element making up the earth, most of which is found in various iron oxides such as; mineral hematite, magnetite, and tactonite. Iron is essential to almost all living things, from micro-organisms to humans. It is an essential part of hemoglobin; the red coloring agent of the blood that transports oxygen through our bodies. Iron may cause conjunctivitis, choroiditis, and retinitis if it contacts and remains in the tissues. Chronic inhalation of excessive *concentration of iron oxide fumes or dusts may result in development of a benign pneumoconiosis, called siderosis, which is observable as an x-ray change.*

Iron (III)-O-arsenite, pentahydrate may be hazardous to the environment; special attention should be given to plants, air and water. It is strongly advised not let these chemical enter into the environment because it persist in the environment.

2.2.2 Cadmium

Cadmium can mainly be found in the earth's crust. It always occurs in combination with zinc. Cadmium also consists in the industries as an inevitable by-product of zinc, lead and copper extraction. After being applied it enters the environment mainly through the ground, because it is found in manures and pesticides. Naturally a very large amount of cadmium is released into the environment, about 25,000 tons a year. About half of this cadmium is released into rivers through weathering of rocks and some cadmium is released into air through forest fires and volcanoes. The rest of the cadmium is released through human activities, such as manufacturing. No cadmium ore is mined for the metal, because more than enough is produced as a byproduct of the smelting of zinc from its ore, sphelerite (ZnS), in which CdS is a significant impurity, making up as much as 3%.

Human uptake of cadmium takes place mainly through food. Foodstuffs that are rich in cadmium can greatly increase the cadmium concentration in human bodies. Examples are liver, mushrooms, shellfish, mussels, cocoa powder and dried sea weed. Cadmium accumulates in kidneys, where it damages filtering mechanisms. This causes the excretion of essential proteins *and sugars from the body and further kidney damage. It takes a very long time before cadmium that has accumulated in kidneys is excreted from a human body.*

Other health effects that can be caused by cadmium are:

i. *Diarrhea, stomach pains and severe vomiting*
ii. *Bone fracture*
iii. *Reproductive failure and possibly even infertility*
iv. *Damage to the central nervous system*
v. *Damage to the immune system*
vi. *Psychological disorders*
vii. *Possibly DNA damage or cancer development*

Cadmium can be transported over great distances when it is absorbed by sludge. This cadmium-rich sludge can pollute surface waters as well as soils. Cadmium strongly adsorbs to organic matter in soils. When cadmium is present in soils it can be extremely dangerous, as the uptake through food will increase. Soils that are acidified enhance the cadmium uptake by plants. This is a potential danger to the animals that are dependent upon the plants for survival. Cadmium can accumulate in their bodies, especially when they eat multiple plants. Cows may have large amounts of cadmium in their kidneys due to this. Earthworms and other essential soil organisms are extremely susceptive to cadmium poisoning. They can die at very low concentrations and this has consequences for the soil structure. When cadmium concentrations in soils are high they can influence soil processes of microorganisms and threat the whole soil ecosystem. In aquatic ecosystems cadmium can bio accumulate in mussels, oysters, shrimps, lobsters and fish. The susceptibility to cadmium can vary greatly between aquatic organisms. Salt-water organisms are known to be more resistant to cadmium poisoning than freshwater organisms. Animals eating or drinking cadmium sometimes get high blood-pressures, liver disease and nerve or brain damage.

2.2.3 Lead

Lead occurs naturally in the environment. However, most lead concentrations that are found in the environment are a result of human activities. Due to the application of lead in gasoline an unnatural lead-cycle has consisted. In car engines lead is burned, so that lead salts (chlorines, bromines, oxides) will originate. These lead salts enter the environment through the exhausts of cars. The larger particles will drop to the ground immediately and pollute soils or surface waters, the smaller particles will travel long distances through air and remain in the atmosphere. Part of this lead will fall back on earth when it is raining. This lead-cycle caused by human production is much more extended than the natural lead-cycle. It has caused lead pollution to be a worldwide issue.

Lead can enter (drinking) water through corrosion of pipes. This is more likely to happen when the water is slightly acidic. That is why public water treatment systems are now required to carry out pH-adjustments in water that will serve drinking purposes. For as far as we know, lead fulfils no essential function in the human body, it can merely do harm after uptake from food, air or water. Lead can cause several unwanted effects, such as:

i. *Disruption of the biosynthesis of haemoglobin and anaemia*
ii. *A rise in blood pressure*
iii. *Kidney damage*
iv. *Miscarriages and subtle abortions*
v. *Disruption of nervous systems*
vi. *Brain damage*
vii. *Declined fertility of men through sperm damage*
viii. *Diminished learning abilities of children*

Not only leaded gasoline causes lead concentrations in the environment to rise. Other activities, such as fuel combustion, industrial processes and solid waste combustion, also contribute. Lead can end up in water and soils through corrosion of leaded pipelines in a water transporting system and through corrosion of leaded paints. It cannot be broken down; it can only converted to other forms. Lead accumulates in the bodies of water organisms and soil organisms. Body functions of phytoplankton can be disturbed when lead interferes. Phytoplankton is an important source of oxygen production in seas and many larger sea-animals eat it. That is why we now begin to wonder whether lead pollution can influence global balances.

2.2.4 Zinc

Zinc is a very common substance that occurs naturally. Many foodstuffs contain certain concentrations of zinc. Drinking water also contains certain amounts of zinc, which may be higher when it is stored in metal tanks. Industrial sources or toxic waste sites may cause the zinc amounts in drinking water to reach levels that can cause health problems. Zinc occurs naturally in air, water and soil, but zinc concentrations are rising unnaturally, due to addition of zinc through human activities. Most zinc is added during industrial activities, such as mining, coal and waste combustion and steel processing. Some soils are heavily contaminated with zinc, and these are to be found in areas where zinc has to be mined or refined, or were sewage sludge from industrial areas has been used as fertilizer. Zinc is the 23rd most abundant element in the Earth's crust. The dominant ore is zinc blende, also known as sphalerite. Other important zinc ores are wurzite, smithsonite and hemimorphite.

Zinc is a trace element that is essential for human health. When people absorb too little zinc they can experience a loss of appetite, decreased sense of taste and smell, slow wound healing and *skin sores. Zinc-shortages can even cause birth defects. Although humans can handle proportionally large concentrations of zinc, too much zinc can still cause eminent health problems, such as stomach cramps, skin irritations, vomiting, nausea and anaemia. Very high levels of zinc can damage the pancreas and disturb the protein metabolism, and cause arteriosclerosis. Extensive exposure to zinc chloride can cause respiratory disorders. Zinc can be a danger to unborn and newborn children. When their mothers have absorbed large concentrations of zinc the children may be exposed to it through blood or milk of their mothers.*

The world's zinc production is still rising. This basically means that more and more zinc ends up in the environment. Water is polluted with zinc, due to the presence of large quantities of zinc in the wastewater of industrial plants. This wastewater is not purified satisfactory. One of the consequences is that rivers are depositing zinc-polluted sludge on their banks. Zinc may also increase the acidity of waters. Water-soluble zinc that is located in soils can contaminate groundwater.

2.3 Impacts of oil spillage on the environment

Oil spills have caused a lot of environmental problems in the Niger Delta. Oil spills have degraded most agricultural lands in the area and have turned hitherto productive areas into wastelands. With increasing soil infertility due to the destruction of soil microorganisms, and dwindling agricultural productivity, farmers have been forced to abandon their land, to seek non-existent alternative means of livelihood. Aquatic life has also been destroyed with the pollution of traditional fishing grounds, exacerbating hunger and poverty in fishing communities

(Gbadegesin, 1997). In a study of the socio-economic impact of oil pollution, stated that crude oil exploitation has had adverse environmental effect on soils, forest sand water bodies in host communities in the Niger Delta. Farmers have lost their lands, and are consequently forced to emigrate to other communities in search of livelihood exerting additional pressures on natural resources in such areas (Omofonmwan and Odia, 2009). It is noteworthy that, the devastating consequences of oil spill in Niger Delta region with its eventual hazards on both aerial and terrestrial environ is tantamount to an irreversible chain effect on both the bio-diversity and safety spills in populated areas affect crops and agriculture through contamination of the ground-water and soils. Spills also contribute to the contamination and death of fishes which affects the economy and human health adversely.

2.3.1 Air pollutions

Refineries are one of the leading sources issuing air pollutants and spreading various greenhouse gases into environment. According to this study, the ratio of extending such pollutants relies on the type and volume of the pollutants, the way of refining, applying or not applying advanced technology and worn out devices, utilizing devices controlling environmental pollution, applicable environmental management and proper ways to preserve oil derivations. Toxic dangerous pollutants usually found in refineries include BTEX, floating particles (PM), all kinds of NO_x, *CO,* H_2S, SO_2, *petrol compositions, toluene, ethylbenzene, gezilen and methane. Spreading out these materials out in the air can be produced by refining procedures and leaking taps or joints. Furthermore, combustion process in high temperatures in furnaces to produce electricity, steam power and the flow of fluids in transition system can all be lead to over-expanding pollutants into the environment (U.S. Environmental Protection Agency, 2001). It is* *obvious that there are high amounts of SO_2 in refineries that can create lung and skin cancer, acid rain and reduce the life of machinery useful life.*

2.3.2 Water contamination

With the development of oil industry, the general environment and in particular wetland ecosystem has become extremely vulnerable to damaging effects of oil pollution. Contamination of aquatic environment by crude oil and petroleum products constitute an additional source of stress to aquatic organisms (Omoregie et al., 1997) and are of importance to the wetland environment. Oil contaminated water resulted in water becoming unsuitable for the growth of macrophytes (Edema, 2006) only scanty data are available for levels of chemical pollution of aquatic plants since most studies of biota are concentrated in fish (FAO, 1993).

Water quality is one important factor of an aquatic environment. Water analysis consists of an assessment of the condition of water in relation to set goals. For example, water samples with decreased electrical conductivity measurement indicate a good measure of purity (Hoagland, 1972). During spillage, water supply becomes critical. Toxic pollutants in water refer to a whole array of chemical which are leached into ground water or which are discharged directly into rivers. Contamination of aquatic environment by crude oil and petroleum products constitute an additional source of stress to aquatic organisms (Omoregie et al., 1997) and are of importance to wetland environment. Water pollutants can also include excessive amounts of heavy metals, radioactive isotopes, faecal coliform bacteria, phosphorus, nitrogen, sodium and other useful (even necessary) elements as well as certain pathogenic bacteria and viruses (Botkin and Keller, *1998). The water environment experiences many dynamic changes induced by various natural events such as the spillage of toxic chemicals that may have significant impact on aquatic life (Camougis, 1981).*

Even in Roman times, heavy metals from mining and pathogens from cities caused serious though local, water contamination (FAO, 1993). Some of the major factors associated with accelerating pace of fresh water pollution is accidental damage of pipes and tankers, major leaks and local spills. These cause varying degrees of aquatic toxicity and material damage. Industrial accidents involving spillage of long lasting pollutants such as persistent organic substances have the most serious effects on water quality. Many of these substances become concentrated in living tissue because organisms have no means of excreting them. They accumulate and are passed on at successively greater concentration of predators higher up the food chain.

2.3.2.1 Marine Contamination

The impact of oil spill on marine life depends largely on the physical and chemical characteristics of the particular oil and the way these changes with time, a process known as 'weathering'. The specific gravity, viscosity, chemical composition and toxicity of the pollutant are the main properties that determine the likely impact of oil on sea organisms. The type of environment oiled is also important, e.g. sandy, rocky, salt marsh or mangrove. When oil spills into the ocean, it's especially likely to harm animals and plants at two interfaces (places where different things come together): (i) Near the surface of the water, where water and air meet, and (ii) Along the shore, where water and land meet.

According to Akpofure (2008) the oil activities in the area has resulted to situations whereby complete polluted water is bequeathed to the children. The communities' shorelines have been *washed away or eroded due to the high volume of deep-sea exploration and exploitation activities.*

With the expansion of oil production, the incidence of oil spills has greatly increased. Available records show that 6,817 oil spills occurred between 1976 and 2001 with loss of approximately three million barrels of oil in the region. Approximately twenty-five percent spilled in swamps and sixty-nine in offshore (UNDP Report, 2006). Besides oil spills as source of water pollution, canalization and wastes discharged into freshwater swamps and into the sea are other sources (Akpofure, 2008). In an attempt to shorten travel time and improve access to oil fields and production facilities, oil companies have constructed canals that in some cases have caused salt water to flow into fresh water zones destroying freshwater ecological systems. The toxic effects of oil on marine life depend on the duration of exposure and oil concentration in the environment. The presence of toxic components does not always cause mortality, but may induce temporary effects like narcosis and tainting of tissues, which usually subside overtime. Oil spills in the ocean destroy small sea organisms, fish, seabirds, sea mammals, shorelines and may contaminate the ocean floor for many years after the event.

In Ibeno, Akwa Ibom State, where Mobil's operations *have reportedly led to the loss of fish populations along the coast, fishing is available only to those who can afford large boat engines* and trawlers to venture into the high seas. The rest of the population must buy "ice fish" (frozen *fish) from commercial fishermen, a practice totally unknown a few years back. Since market prices are constantly on the rise, many villagers have to go without fish. Only a small sector of* the local population in Ibeno finds employment in Mobil's facilities, and thereby earns *money to buy food.*

2.3.2.2 Fresh water and groundwater contamination

In fresh waters, oil contamination can result in severe impacts on the habitat because the movement associated with water is minimal, as compared to marine environment. Stagnant water bodies cause the oil to remain in the environment for long, resulting in prolonged exposure of the plants and animals (Chindah, 2000). In the case of flowing streams and rivers, the oil not only tends to collect on plants and grasses growing on the banks but also interacts with sediments, thereby affecting the organisms. In cases where a stream that provides potable water is affected by a spill, the people in the area will suffer the problem of obtaining potable water.

2. 4 Institutional Framework.

2.4.1 National Environmental Policy and Water Resource Management

From the onset of British rule in the 1900s, Nigeria's environmental protection effort had been *through the colonial bye-laws. The colonial economic development policies and plans contain little or no stringent rules to conserve the natural resources or limit pollution (Adelegan, 2004). The major laws on pollution include Criminal Code of 1958. The fines and penalties were liberal and the laws were quite often poorly enforced.*

Thus the formative years of Institutional environmental regulation in Nigeria could be said to have been characterized by the absence of clear scientific criteria and standards on pollution levels with enforcement of basic environmental and household hygiene depended largely on qualitative legal rules (Chokor, 1993). Water pollution remains a major problem in the Nigerian environment. Both urbanization and industrialization have contributed to the scale of pollution. There were no incentives for adoption of pollution abatement measures and very few disincentives, if any, for polluting the environment. The Federal Constitution of 1979 centered on environmental hygiene, with emphasis on refuse clearance, and management of liquid and solid waste in abattoirs, residential homes and streets, all of which came under the supervision of local government councils (Ola, 1984).

It is instructive to note that it required the dumping of toxic and hazardous waste (made up of principally polychlorobiphenyls – PCBS) in Nigeria by an Italian ship in 1988 and the hostile media reaction that accompanied the discovery that hastened the creation of the then Federal Environmental Protection Agency (FEPA) now Federal Ministry of Environment, since Nigeria lacked both the institutional and legal framework to tackle the issue. Decree 58 of 1988 that set up FEPA required it to establish environmental guidelines and standards for the abatement and control of all forms of pollution, especially in the area of water quality, effluent discharge, air and atmospheric quality and including the protection of the ozone layer which in the past was absent (Federal Government of Nigeria, 1988).

*Following the scenario that brought about the setting up of FEPA, industrial pollution was thus regarded as a priority enviro*nmental problem and hence the first ever and only "National

Guidelines and Standard for Environmental Pollution Control" was more of an industrial *pollution control guidelines and standards with few notes as guidelines for surface impoundments, land treatments, waste piles, landfills, incineration and hazardous/toxic waste. Moreover, even the available industrial pollution control guidelines and standards are not sound enough and are far from been enforced in the country as it were presently. The main legislation for the protection of water resources is scanty. There were no specific regulations and penalties on the chemical and industrial pollution on water in Nigeria.*

From the 1990s, Nigeria began to place some level of priority on soil-related environmental issues. This is reflected in recent environmental policy, legislation, action plans and programme. In 1991, FEPA issued a specific groundwater protection regulation that must be adhered to by Pollution prone industries (FEPA, 1991). Industrial sites were to meet concentration limits for their effluents. These are specified in facility permits issued to the industries and enforcement takes place by compliance monitoring.

CHAPTER THREE

MATERIALS AND METHODS

3.1 The Study Area

The study was carried out in two Okrika Communities: Abam Ama in Okrika Local Government Area and Abuloma in the Port Harcourt City Local Government Area. The two communities are separated by the Okpoka Creek an arm of the Bonny River. Abam Ama is one of the communities sharing boundary with the Port Harcourt Refining Company as a result it is a semi-urban settlement. Petroleum Tankers often park along the major Abam Ama Road waiting to lift refined petroleum products. This community is one of the few Okrika Communities that practice both fishing and farming as sedentary/subsistence agriculture. Abuloma on the other hand is a semi industrial settlement because of its proximity with the Trans Amadi Industrial Complex; and as a result of its strategic position being straddled between Okpoka creek and Primrose creek it's *also serves as marine base for many maritime companies including sea going vessels.*

Generally, Port Harcourt City Local Government Area, Okrika Local Government Area along with Obio/Akpor LGA, and parts of Eleme, Ikwerre, Oyigbo, Ogu/Bolo and Etche Local Government Areas are known as Greater Port Harcourt Metropolis. Port Harcourt Metropolis being the hub of oil and gas industry in the country has attracted various people to the area leading to a burgeoning population of about 760, 843 in both LGAs (Port Harcourt LGA 538,558; Okrika LGA 222,285) as at 2006 census. Figures 3.1.and 3.2 show how the urban space increased several fold to reflect the increasing population of Port Harcourt City. Abuloma was a light build up in 1986 but 2006 is a heavily built-up urban centre.

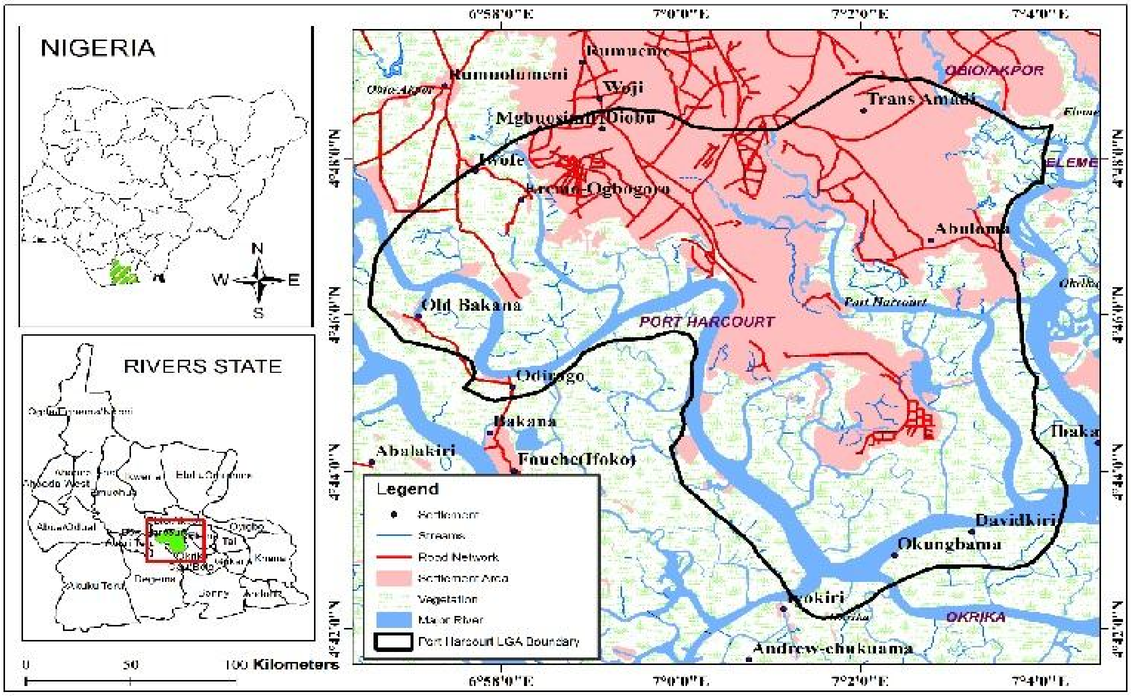


Fig 3.1A: Port Harcourt City Local Government Area Study Area

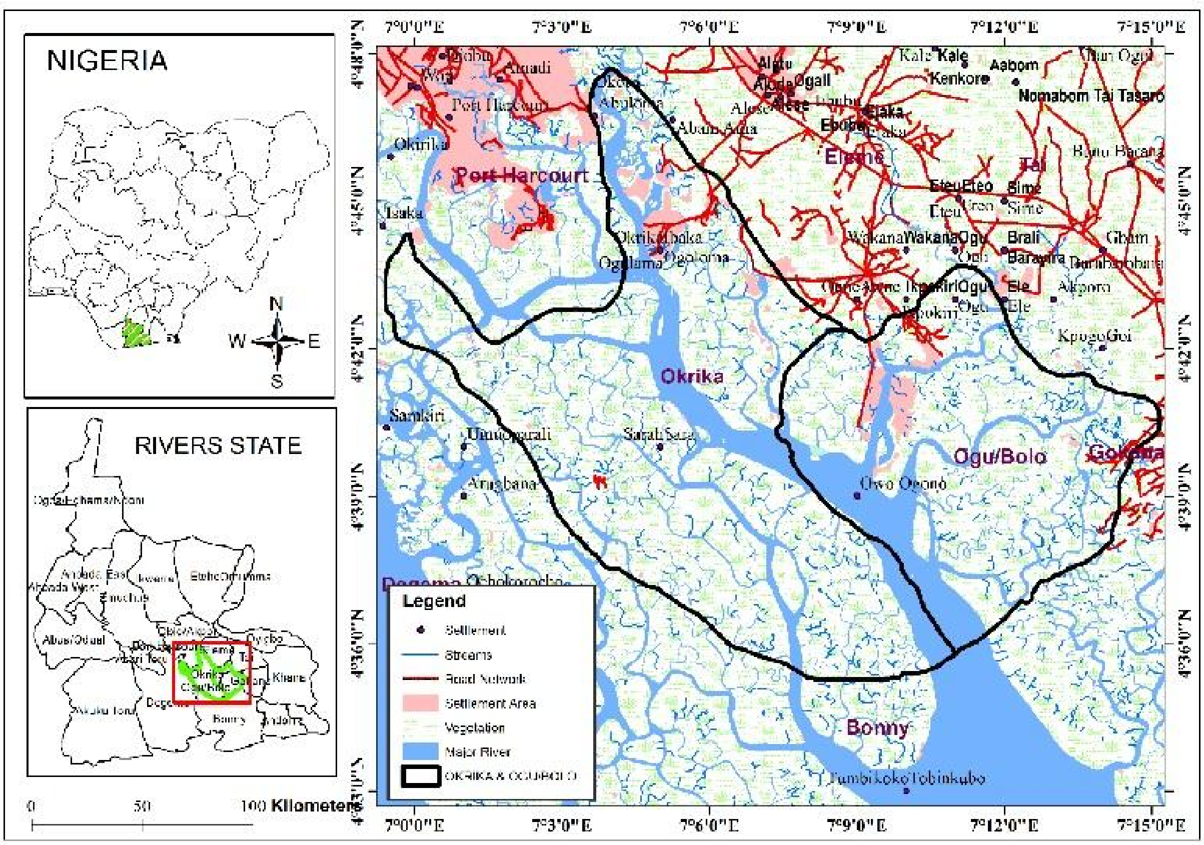


Fig 3.1 B: Okrika Local Government Area Study Area

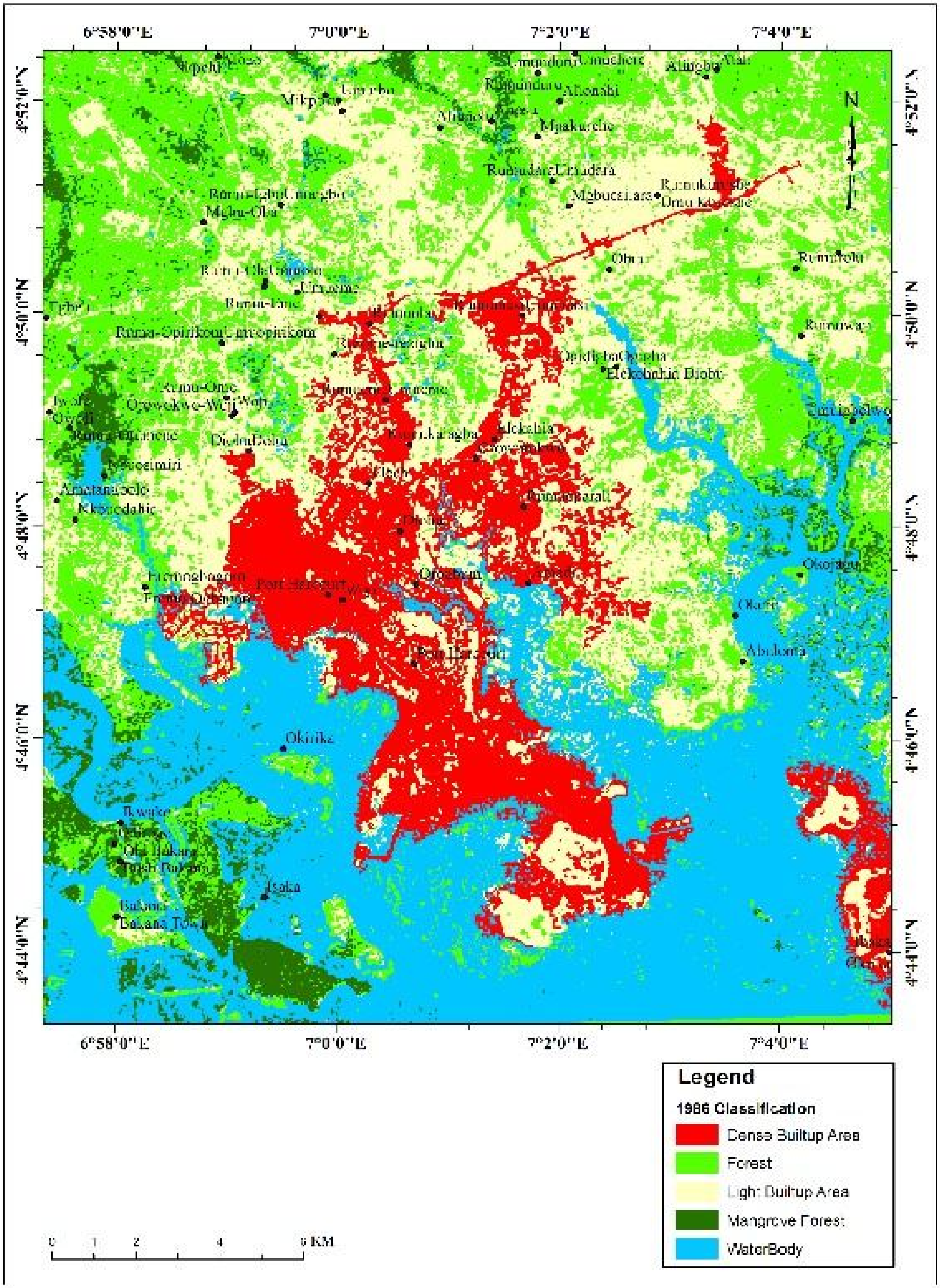


Fig 3.2 1986 Satellite image Landuse/Landcover classification of Port Harcourt & Parts of Okrika showing Abuloma and Abam Ama

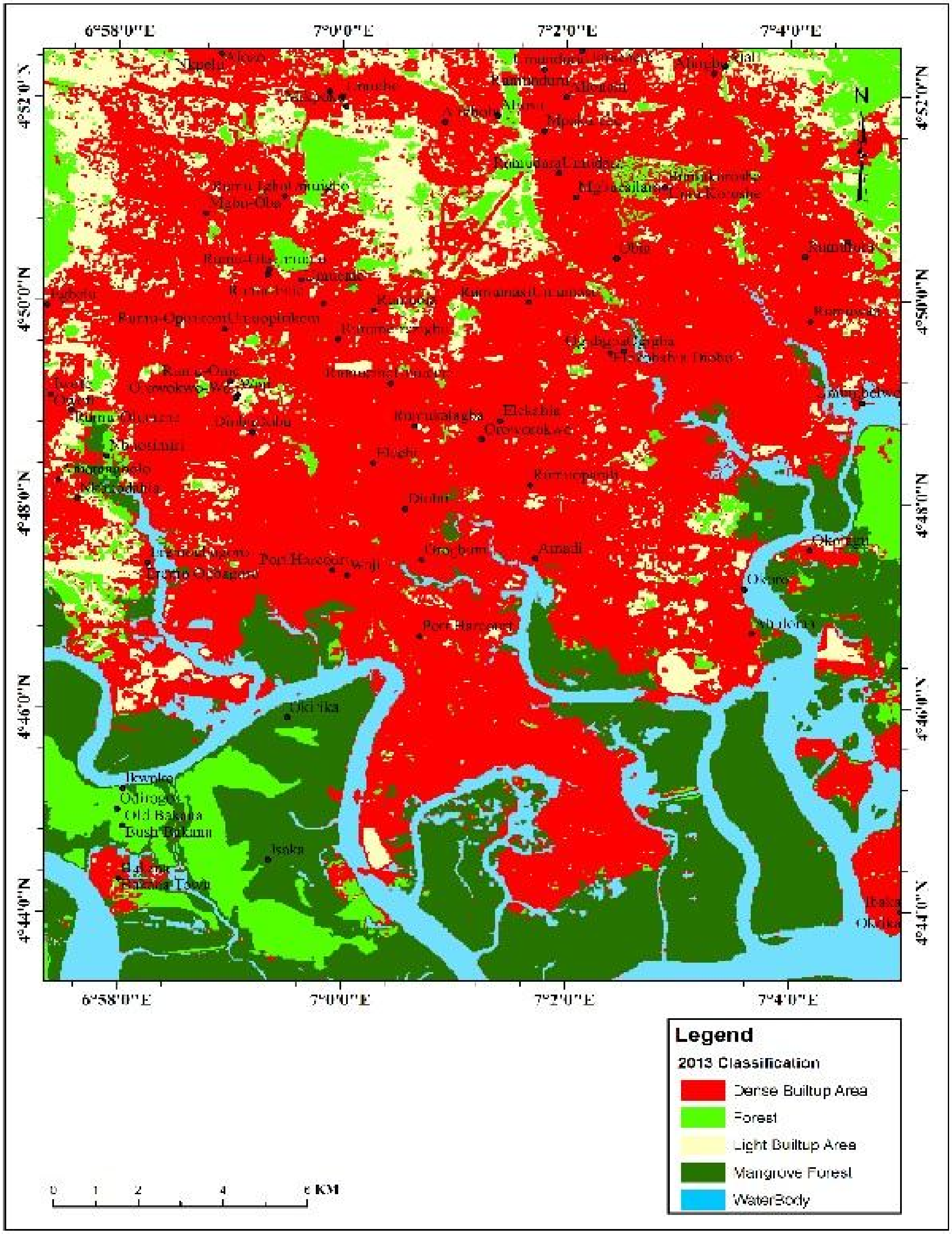


Fig 3.3 2013 Satellite image Landuse/Landcover classification of Port Harcourt & Parts of Okrika showing Abuloma and Abam Ama

3.1.1 Physiographic/Geomorphologic Setting

Geomorphologically, the study area is generally low-lying with elevation between 8 -24m above mean sea level and slopes gently towards the Atlantic Ocean. The drainage pattern is largely controlled by the Bonny River and its tributaries and creeks which together drain various outcrops of relatively higher land which are largely surrounded by mangrove swamps, (Bell-Gam, 2002). The physiography conforms to the geomorphic features of the Niger Delta governed by several factors which influence transport and ultimate deposition of the sediment load, shape and growth of the delta. The Niger Delta comprises five geomorphic sub-environments; the undulating lowlands of the coastal plain sands, the flood plain of the lower Niger with extensive sand deposits, the meander belts consisting of wooded freshwater swamps, the mangrove swamps and estuary complexes and the beach ridges. These sub-environments are zones where a vast amount of sediments are deposited by rivers in their search for lines of flow, (Osakumi and Abam, 2004).

Abam Ama Community is located on an elevation of about 24m above mean sea level with a slope of about 11% generally ensuring that all flows (both surface and sub-surface) are in the South-West direction. While the Abuloma Community is 28m above mean sea level, part of its surface runoff flows into the Okpoka Creek on the eastern Section while the others flow into the Primrose creek on the South Western (Fig 3.3) The proximity of the aquifers to the surface, flat topography, high annual rainfall, and permeable soil media contributes to insignificant runoffs in the site, and implies that the total precipitation goes into storage. This enhances decomposition activities by bacteria and fungi and leaching of contaminants into the aquifer

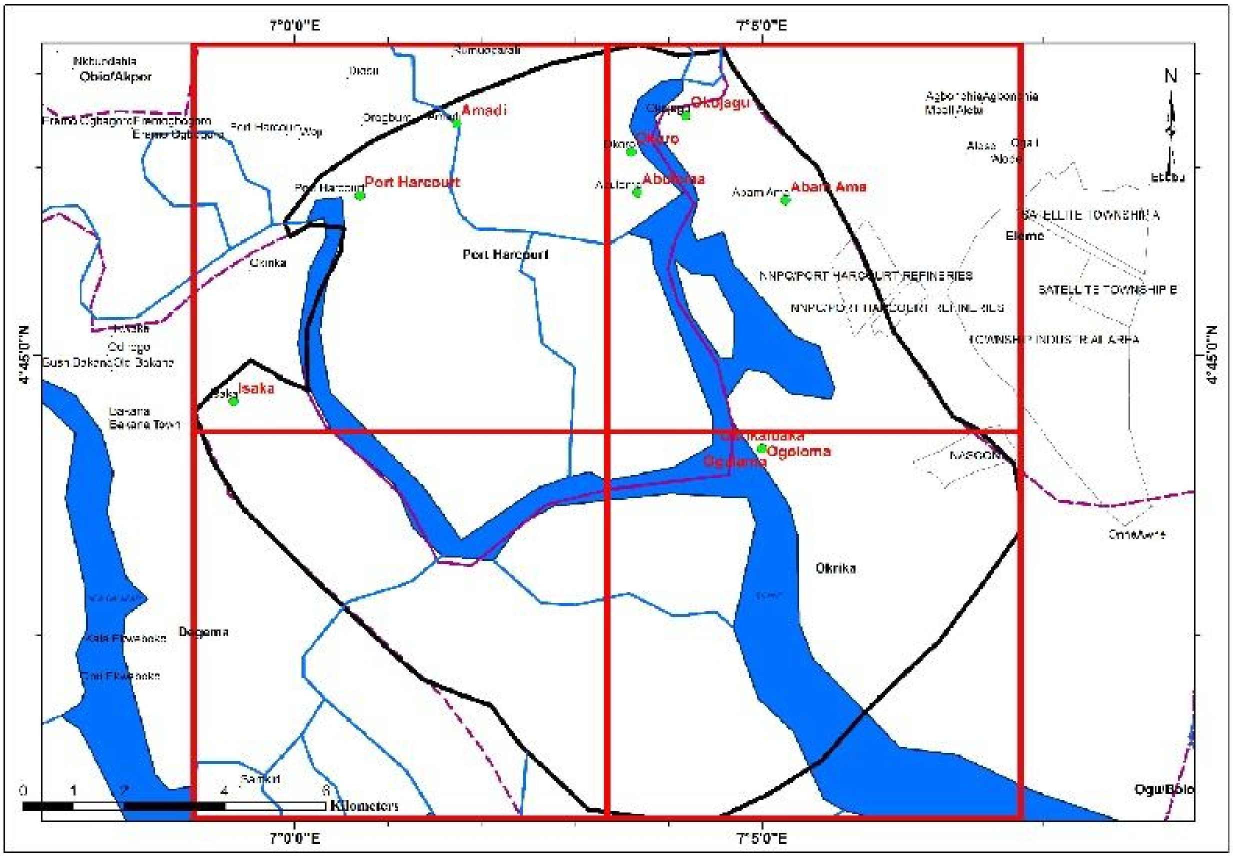


Fig 3.3 GIS generated map of both Port Harcourt and parts of Okrika Local Government Area showing transects where sampling were done.

3.1.2 Geology/Hydrogeology

Port Harcourt and Okrika LGAs like the rest of the LGAs in the Port Harcourt Metropolis are located within the quaternary coastal plain of the lower Niger with extensive alluvium deposits. The area is geologically composed of various Quaternary deposits that overlie the three main stratigraphic units of Benin, Agbada and Akata. The Benin Formation (Oligocene to Recent) is the aquiferous formation in the study area and is exploited for groundwater supplies (Akpokodje, 2001). Although a depth of 100m is most exploited, about 300m depth has been exploited for water (Ngah, 1990). The Benin Formation consists essentially of massive and highly porous sands and gravels with a few thin clay intercalations. The uppermost section of the Benin Formation is the Quaternary deposits of about 40- 150m thick and comprises of rapidly alternating sequences of sand and silt / clay with the later becoming increasingly more prominent seawards (Etu-Efeotor and Akpokodje, 1990). The formation consists of predominantly freshwater continental friable sands and gravel that have excellent aquifer properties with occasional intercalations of claystone/shales (Olobaniyi & Oweyemi, 2006). The Benin Formation is highly permeable, prolific and productive and is the most extensively tapped aquifer in the Niger Delta. All the boreholes in the study area are drilled into the Benin Formation (Etu-Efeotor, 1981; Etu-Efeotor & Akpokodje, 1990; Offodile, 2002); Udom et al., 2002) .

The lithology consists of massive, highly porous and permeable freshwater bearing sands and sandstones with minor clay beds that form the main source of water supply to the city. Alluvium forms the surface blanket for the coastal plain sands, (Hospers 1971). They are sufficiently *recharged by precipitation and surface water bodies. Static water levels are generally shallow, varying between 2 and 8m and getting closer to the surface near the coast. Groundwater flow is generally in the NE-SW trend in line with the regional trend in the basin, (Ehirim and Ebeniro 2006) Water quality increases with depth with the thick sequence of sands forming the major aquifers in the area while the clays form the aquitards. The water table in the area shows appreciable seasonal fluctuations, rising with the rains and declining during dry season.*

3.1.3 Climate and Vegetation

Weather over the area is governed by the moist tropical maritime masses from the Atlantic Ocean and the dry dust landed tropical continental air mass from the northern part of the country commonly called the North East trade winds. The prevalent wind direction in the study area is south-westerly with speed ranging from 0.3 to 4.5m/s and north –easterly with speed between 0.3 – 1.5m/s. As a result of these air masses rainfall is high with annual mean of 2400mm from the inland to about 4000mm at the Coast. The rainfall exhibits double maxima regime with peaks in July and September. The area falls within the humid tropics with humidity of 63- 79%, (Korean Report, 1980). There are two major climatic seasons – the Wet Season (April – October) and Dry Season (November – March).

The climate of the area is marked by high relative humidity (R.H) spread over the year from 8 - 10 months however, specifically, R.H oscillates between 85% and 95% in the Wet Season and decreases to 45% in the Dry Season months. Ambient air temperature ranges from 24°C to 32°C in the Wet Season and 25°C to 36°C in the Dry Season. The vegetation of the area is predominately the tropical rainforest and riparian regime type(the principal specie is rhizophora racemose - red mangrove, Avicennia Africana – white mangrove) constituting about 90% of the *area which is comparatively uniform throughout the proximity of the region. There also exist other vegetation types such as farmland/fallowing mosaic and the exotic Nympa palm.*

3.1.4 Population and Economic Activities

The population of both Local Government Areas is 760,843 with a growth rate of 2.84 %.(FGN, 2009). The major traditional occupation of the inhabitants is subsistence agriculture (sedentary farming and fishing) however; sedentary occupation has gradually taken over farming. Being the hub of oil and gas industry, there are several oil and gas companies employing quite a number of people leading to haphazard and unplanned housing, gridlock transportation and waste generation. Of recent, artisanal refining (an illegal activity of stealing crude oil from product pipeline and refining them for sale has become a major business with its attendant toll on the people and the environment (Amangabara and Njoku, 2012; Obenade and Amangabara, 2014)

3.2 Nature and Sources of Data

The data used for this project were obtained in varied ways but they fall under either of primary or secondary data sources.

3.2.1 Primary Data Sources

The primary data are sets of data collected from the study area through the collection of and analysis of samples and include those derived from observations made during the sampling and laboratory results.

3.2.2 Secondary Data Sources

Secondary methods involved using data already acquired by another party (usually through the primary methods). This work made use of the following secondary data: textbooks, monographs, lecture notes, journal articles, periodicals internet sources and other people's unpublished *academic thesis*

3.3 Sample Population, Sample Size and Sampling Techniques

On the basis of clusters of activity and residential areas four sampling stations each 500m apart was established for each of the study location (i.e. Abam Ama and Abuloma) At these sites, replicate soil samples were collected on three different days between the hours of 07:00 - 11:00am. Table 3.1 describes each of the sampling Stations.

Table 3.1 Sample Locations

S/No.	*Location*	*Town*	*LGA*	*Activity*	*Distance*
1.	*Abam-Refinery Rd*	*Abam*	*Okrika*	*Truck Park*	*500m*
2.	*Near APC Party Sect.*	*Abam*	*Okrika*	*Truck Park/Residential*	*500m*
3.	*Abam – Island Road*	*Abam*	*Okrika*	*Industrial/Marine/bunkering*	*500m*
4.	*Abam – Oba Waterside*	*Abam*	*Okrika*	*Marine/bunkering/farming*	*500m*
5.	*Abuloma Waterside*	*Abuloma*	*Port Harcourt*	*Marine*	*500m*
6.	*Okilo Road*	*Abuloma*	*Port Harcourt*	*Marine/Industrial*	*500m*
7.	*Ejuan/Odili Road*	*Abuloma*	*Port Harcourt*	*Industrial/Residential*	*500m*
8.	*Okuru-Abuloma Rd (Golf Estate Road)*	*Abuloma*	*Port Harcourt*	*Commercial/Residential*	*500m*

Source: Author's Field work

3.4 Instrumentation/method of collection of Soil Sample

Soil samples were collected with the aid of a well calibrated stainless steel hand dug soil auger (2.50 cm in diameter) from eight (8) sampling points at the depth of 0-30 cm. Four soil samples were collected and made into a composite soil samples from Abuloma while another four soil samples were collected and made into a composite soil samples from Abam Ama as described above. The soil samples were immediately transported to the laboratory for standard chemical analyses.

3.5. Laboratory Analyses Soil Quality (Chemical/Heavy mental Determination)

3.5.1 Determination of pH

Twenty grams of air dried soil samples were weighed into a 50mL beaker and 20mL distilled water was added and allowed to stand for 30mins. The solution was filtered and the filterate used to determine pH of soil sample. Hach pH meter was used to determine the pH. Meter was calibrated using pH calibration buffer solution for pH 4, 7 and 10. The electrode of the meter was dipped into the filtrate and the pH meter readings taken to the nearest 0.05unit.

3.5.2 Determination of conductivity

Twenty grams of air dried soil samples were weighed into a 50 mL beaker and 20 mL distilled water was added and allowed to stand for 30 mins. The solution was filtered and the filtrate used to determine the conductivity of soil sample. Hach conductivity meter was used to determine the conductivity. The conductivity meter was calibrated using conductivity calibration solution. The *electrode of the meter was dipped into the filtrate and the conductivity meter readings taken to the nearest 0.05unit.*

3.5.3 Determination of heavy metals

One gram of the dried fine soil sample was weighed and transferred into an acid washed, round bottom flask containing 10 cm^3 concentrated nitric acid. The mixture was slowly evaporated over a period of 1hour on a hot plate. Each of the solid residues obtained was digested with a 3:1 concentrated HNO_3 and $HClO_4$ mixture for 10 m at room temperature before heating on a hot plate. The digested mixture was placed on a hot plate and heated intermittently to ensure a steady temperature of 150°C over 5 hours until the fumes of $HClO_4$ were completely evaporated (Jacob et al., 2009). The mixture was allowed to cool to room temperature and then filtered using Whatman No.1 filter paper into a 50 cm^3 volumetric flask and made up to the standard mark with deionized water after rinsing the reacting vessels, to recover any residual metal. The filtrate was then stored in pre-cleaned polyethylene storage bottles ready for analysis. Heavy metal concentrations were determined, each with a specific lamp using an Atomic Absorption Spectrophotometer (AAS) AA600 Series.

3.5.4 Determination of Total Petroleum Hydrocarbon (TPH) in soil

Ten grams (10g) of the sample was weighed into extraction bottle and 20mL of extraction mixture (DCM: Hexane: acetone) in ratio 2:2:1 was added. The mixture was sonicated for 1hr and the organic aqueous layer was decanted. Extracted organic phase was dried using anhydrous sodium sulphate salt and concentrated using vacuum rotary evaporator gas to about 1.0mL. Round bottom flask was rinsed to make the final volume of the extract to 1.0ml. One microlitre

(1.0 µL) of the final extract was injected into already calibrated Gas Chromatograph (HP 5890, USA) equipped with capillary column. The peak areas are used in the quantifications. All QA/QC procedures were strictly followed.

Extract was fractionated by using column packing. The column was packed by placing 1g of glass wool into the column and gently packed. One milliliter (1ml) of silica gel was placed on it and 1ml of sodium sulphate was added on top of the silica gel. The column was pre-conditioned by running 10mL of n-hexane through the column. One milliliter (1ml) of the concentrated extract was placed on the column and eluted with 10mL n-hexane. Eight milliliter (8ml) of the eluents was taken and discarded and the remaining 2mL was collected and kept in a 2mL vial for ALIPHATICS.To the same column, 10mL of DCM was allowed to drain through the column and 8mL of the eluent was collected and discarded. The remaining 2mL was collected into a vial and kept for AROMATICS. One microlitre (1.0 µL) of the aromatic and aliphatic extract was injected into already TPH calibrated standard GC and result was expressed in mg/kg.

3.5.5 Determination of Cation Exchange Capacity of the soil samples

The cation exchange capacity (CEC) of a soil is a measure of the quantity of negatively charged sites on soil surfaces that can retain positively charged ions (cations) such as calcium (Ca^{2+}), magnesium (Mg^{2+}), and potassium (K^{+}), by electrostatic forces. Cations retained electrostatically are easily exchangeable with cations in the soil solution so a soil with a higher CEC has a greater capacity to maintain adequate quantities of Ca^{2+}, Mg^{2+} and K^{+} than a soil with a low CEC. A soil with a higher CEC may not necessarily be more fertile because a soil's CEC can also be *occupied by acid cations such as hydrogen (H^{+}) and aluminum (Al^{3+}). However, when combined with other measures of soil fertility, CEC is a good indicator of soil quality and productivity.*

The method used by Burt (2004) was adopted. Ten (10g) grams of air-dried soil ground to less than 2 mm was weighed and placed into a 250 ml beaker. Twenty five milliliters (25 mL) of NH_4OAc was to the soil. It was covered and let to set overnight. For each sample, a 7 cm Buchner funnel was prepared by fitting it with a 7 cm Whatman No. 42 filter paper. The filter was wetted with a minimum amount of NH_4OAc. The funnel was inserted into a 250 ml suction flask. The vacuum pump was turned on to seat the moistened filter. The soil-NH_4OAc mixture was stirred and transferred into the filter. Approximately 75 mL NH_4OAc for each sample was measured into a plastic squirt bottle with one bottle for each sample. About 10 mL of the NH_4OAc was used in the bottle to transfer all of the soil to the Buchner funnel. The soil was covered with a 7.0 cm Whatman No. 1 filter paper to keep the soil moist between leachings. The soil was leached 5 to 7 times with 10 to 15 ml increments of NH_4OAc. The leachate was transferred to a 250 mL volumetric and brought to volume with 1 M NH_4OAc. The solution was analyzed for Ca, Mg, K, and Na using atomic absorption spectrophotometry.

3.6. Laboratory Analyses Soil Quality (Physical/Geotechnical)

Grain size is one of the suitability criteria of soils, information obtained from grain size analysis can be used to predict soil-water movement. The grain-size analysis is an attempt to determine the relative proportions of the different grain sizes that make up a given soil mass. This is accomplished by obtaining the quantity of material passing through a given sieve opening but retained on a sieve of smaller sized openings and then relating this retained quantity to the total sample. It is evident that the material retained on any sieve in this manner consists of particles of many sizes, all of which are smaller than the openings of the sieve through which the materials *passed but larger than the openings of the sieve on which the soil is retained. A reduction in soil aggregate stability implies an increase in soil degradation since it is a measure of structural stability of soils. The sieves are made of woven wire with rectangular openings ranging in size from 101.6mm in the coarse series to the No. 400 (0.038mm) in the fine series. A mechanical or automated sieve shaker, weighing balance, a triple beam balance, a metal brush, a pestle and mortar and a hand trowel.*

3.7 Statistical Analysis

Descriptive statistics was explored to obtain means, standard error, range and graphical representations of ensuing data. The interrelationships existing between the soil samples and their variability were explored using the Analysis of Variance (ANOVA).The t- test was used to compare means of both WHO and Soil samples to determine pollution or contamination threats.

CHAPTER FOUR

PRESENTATION AND DISCUSSION OF RESULTS

4.1 pH and Heavy Metal Characteristic of Sampled Soils

The results of the laboratory analyses (Heavy metal, Gradation test) as well as health records from Health centres in the area are presented in this chapter. Table 4.1 shows the Heavy metal and total petroleum Hydrocarbon content in Soilwhile Tables 4.2; 4.3; and figs 4.1 – 4.4 shows result of Gradation test, Atterberg limits, Bulk Density and Percentage passing. While Table 4.4 is the summary of all geotechnical soil analysis results with some hydraulic parameters of the soil

Table 4.1 Heavy Metal Concentration Sampled Soils (mg/kg)

Samples	pH	Mn	Cu	Cr	Cd	Pb	Zn	Fe	K	CEC	TPH
NESREA(2007)			*100*	*100*	*3*	*140*	*421*		*140*	*(cmol/Kg)*	*1000*
ARR	5.5	35.58	9.1	1.11	2	1.85	434	388	23	4.62	3456
APC	6.2	37.45	6.74	0.25	0.4	0.69	159	139	33	2.09	1469
AIR	6.4	9.167	6.93	0.06	1	1.59	49	443	18.09	2.56	2203
AOW	6.1	37.79	6.01	0.75	0.34	1.45	98	552	42.06	4.23	2212
min	5.5	9.167	6.01	0.06	0.34	0.69	49	139	18.09	2.09	1469
max	6.4	37.79	9.1	1.11	2	1.85	434	552	42.06	4.62	3456
Mean	**6.05**	**29.99675**	**7.195**	**0.5425**	**0.935**	**1.395**	**185**	**380.5**	**29.0375**	**3.375**	**2335**
AWS	5.9	37.44	2.05	0.98	2.36	1.37	821	558	38.61	3.56	20342
OKILO	5.5	15.67	7.09	0.88	0.21	0.85	46	297	43.01	4.11	14689
EJUAN	6.3	3.67	1.35	0.22	0.28	0.305	36	149	38.7	5.01	3232
OAR	6.2	276	3.65	1.03	0.98	0.605	77	532	32.2	3.9	3345
min	5.5	3.67	1.35	0.22	0.21	0.305	36	149	32.2	3.56	3232
max	6.3	276	7.09	1.03	2.36	1.37	821	558	43.01	5.01	20342
Mean	**5.975**	**83.195**	**3.535**	**0.7775**	**0.9575**	**0.7825**	**245**	**384**	**38.13**	**4.145**	**10402**

** ARR= Abam-Refinery Rd; APC = Near APC Party Secretariat; AIR = Abam – Island Road. AOW =Abam – Oba Waterside. AWS = Abuloma Waterside. OKI = Okilo Road. EOR= Ejuan/Odili Road, OAR= Okuru-Abuloma Rd*

The soil quality test of the study area according to Table 4.1 shows that soil pH for both Abam Ama and Abuloma are acidic. The pH values recorded for each sampling location ranged from 5.5 to 6.4 at Abam Ama and Abuloma. The mean concentration of all sample locations in Abam Ama is 6.05 and Abuloma is 5.9 Comparing both communities, Abuloma soils are more acidic than Abam Ama possibly as a result of the industrial nature of the area, at such levels there tend to be an increased micronutrient solubility and mobility promoting heavy metal concentration in the soil as evidenced in the elevated levels in both Abam and Abuloma soil samples ofmanganese, iron, zinc and sodium.

Results obtained in this study as shown in Table 4.1 furthered revealed the concentrations of toxic metals in the soil samples for example minimum value for Manganese (Mn) for Abam is 9.167mg/kg and max 37.79mg/kg. In the Abuloma area, there was observed a wide variations of values of Mn (Min = 3.67mg/kg and max = 276mg/kg) the mean values for both Abam and Abuloma are 29.9mg/kg and 83mg/kg an indication that Abuloma area is more predisposed to elevated levels of Mn. The table also showed elevated levels across all sampling points of Zinc (Zn), Iron (Fe) in both Abam Ama and Abuloma Communities mean values for Zn for both communities are 185mg/kg and 245mg/kg respectively, this indicates that leachate from the decomposed wastes carry high concentration of metals that can cause severe pollution.

However, some heavy metals e.g. Copper (Cu), Chromium (Cr), Lead (Pb) have lower concentration in the soil samples in both communities. It was also observed from the table that all analysed parameters except for Cu (7.195mg/Kg, 3.535mg/kg) and Pb (1.395mg/kg, 0.7825mg/kg) are higher in concentration in Abuloma than Abam Ama. It would have been expected that Abam Ama a neighborhood community to the Port Harcourt Refinery should have *a higher/elevated levels of TPH however, this was not so perhaps due to the fact that Abuloma Waterside and Okilo road in Abuloma are serviced by marine vessels as well as the activities of illegal oil bunkers who spill products during transportation to their selling points.*

Comparing the values to National Environmental Standards and Regulatory Agency (NESREA, 2007), The values of TPH for both Abam and Abuloma, CEC for Abam and Abuloma, Sodium for Abam and Abuloma, Iron for both Abam and Abuloma, Zinc for Abuloma alone, Manganese for Abuloma alone are above the permissible levels while Chromium, Cupper, Cadmium and Lead are below the limits (however some are approaching the cut-off mark) the finding are in line with reports in literature. Usually when soil becomes acidic it generally enhances the elevation of manganese, aluminum, zinc and iron.

Total Petroleum Hydrocarbon is far above the limits set by the regulatory body (NESREA, 2007) for soil. The mean concentration of TPH for Abam Ama is 2,335 compared to 10, 402 for Abuloma. Generally, Abam Ama is close to the Refinery so, many trucks line up its road to load products from which there are reported spills. Of recent, activities of illegal bunkers operating artisanal refinery (Kpoa fire or Bush Refinery) have added to this elevation as safety and environmental standards are thrown off board. At the Abuloma axis, bunkering activity is higher both by illegal bunkers and marine vessel owners. Granted that TPH are volatile, its volatility also contributes to its capacity to pollute the soil. When TPH are scavenged off the air, the return to the soil when rain falls or when wind settles down, the soil in this case acts as repository.

4.2 Gradation (Grain Size Analysis) of Sampled Soil

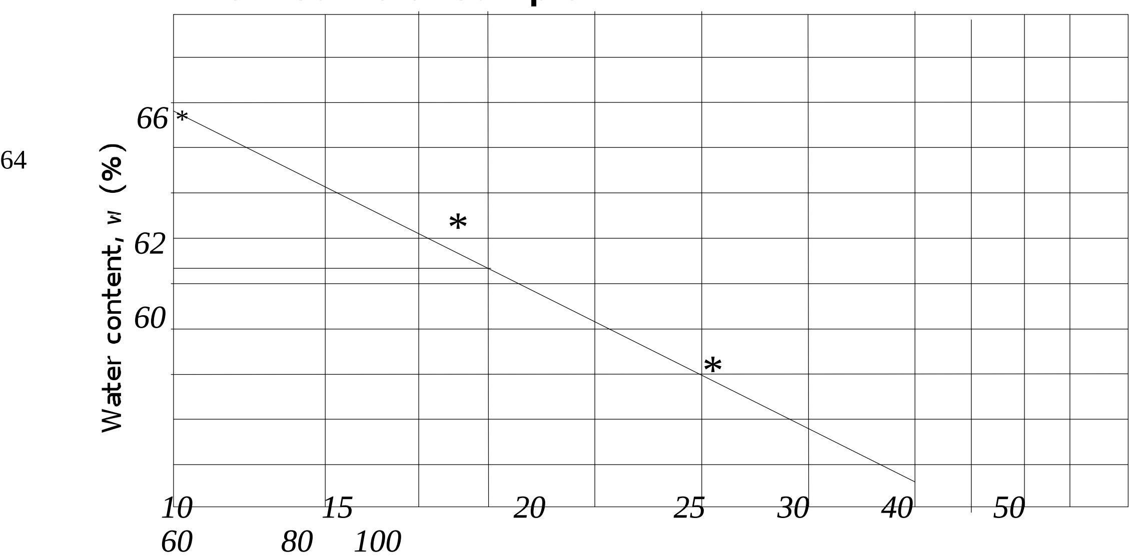
Thelaboratory results for the geotechnical analysis of the soil in the study area are presented as Table 4.2 to 4.4 (Atterberg limits, Bulk Density, percentage passing and Particle Size distribution) and from these various tables, charts and graphs table 4.2 is derived as representative of the soil sample in the study area.

Table 4.2 ATTERBERG LIMITS DETERMINATION

Liquid Limit Determination

Trial No.	1	2	3
Can Identification No.	33	24	37
No. of blows	11	23	41
Wt. of wet soil + can (g)	40.1	39.0	44.8
Wt. of dry soil + can (g)	31.8	31.2	35.3
Wt. of can (g)	19.3	18.9	19.5
Wt. of dry soil (g)	12.5	12.3	15.8
Wt. of moisture (g)	8.3	7.8	9.5
Water content, W, %	66.2	63.5	60.1

Flow Curve of Sample



Liquid Limit = <u>63%</u>

Plastic limit = <u>47.7%</u>

Plasticity index I_p = <u>15.5%</u>

Plastic Limit Determination

Can Identification No.	24
Wt. of wet soil + can (g)	25.4
Wt. of dry soil + can (g)	23.3
Wt. of can (g)	18.9
Wt. of dry soil (g)	4.4
Wt. of moisture (g)	2.1
Moisture content, w, (%)	47.7
Plastic limit (w_p) (%)	47.7

Table 4.3

Determination of Bulk Density

Bulk Density Determination	**Abam 1**	**Abam II**	**Abuloma I**	**Abuloma II**
Wt of Ring + sample (g)	*123.0*	*124.8*	*124.6*	*125.5*
Wt. of Ring (g)	*60.7*	*60.7*	*60.7*	*60.7*
Wt. of sample (g)	*62.3*	*64.1*	*63.9*	*64.8*
Volume of sample (CM^3)	*39.3*	*39.3*	*39.3*	*39.3*
Bulk density (mg/m^3)	*1.59*	*1.63*	*1.63*	*1.65*

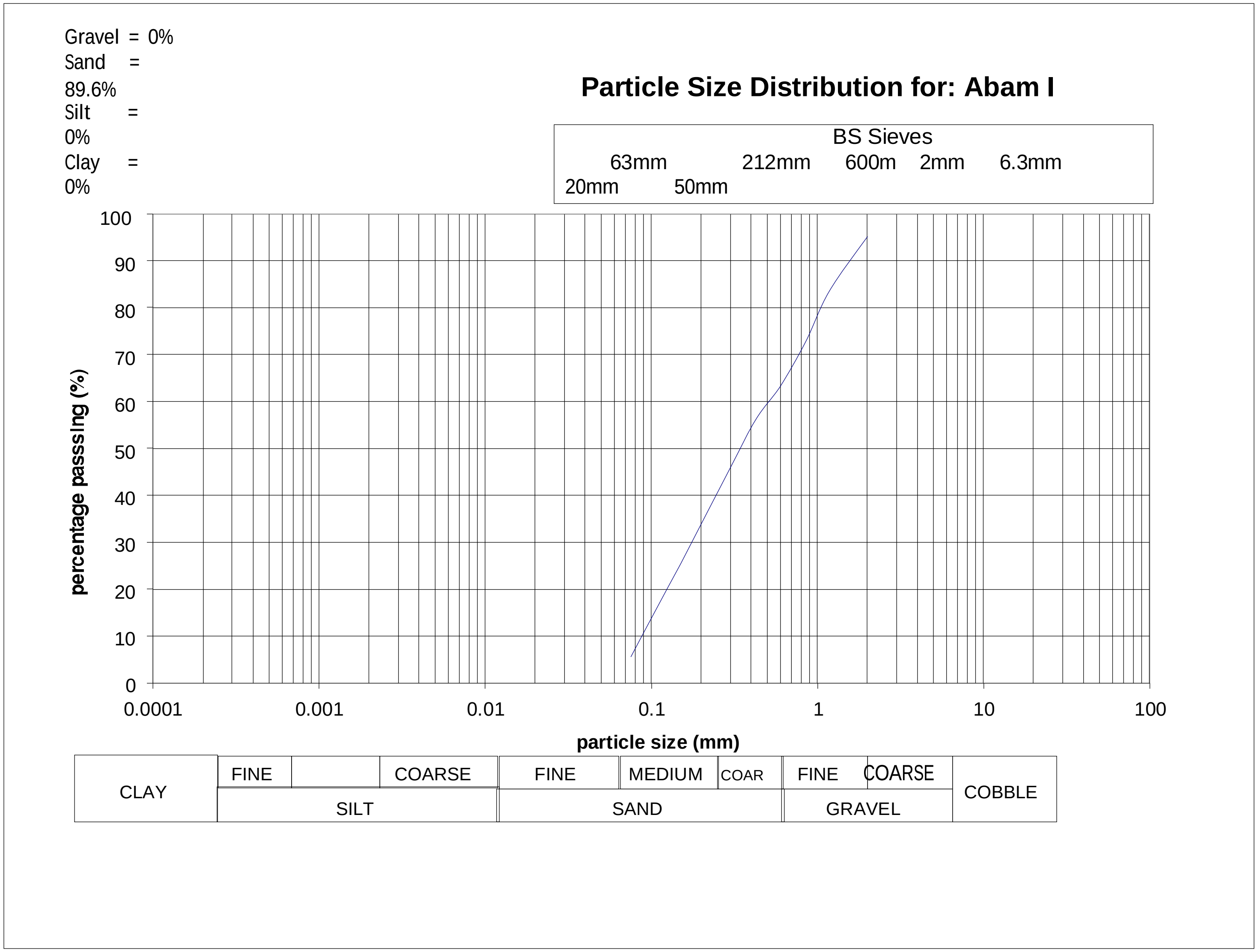


Fig 4.1: Particle Size Distribution for Abam I

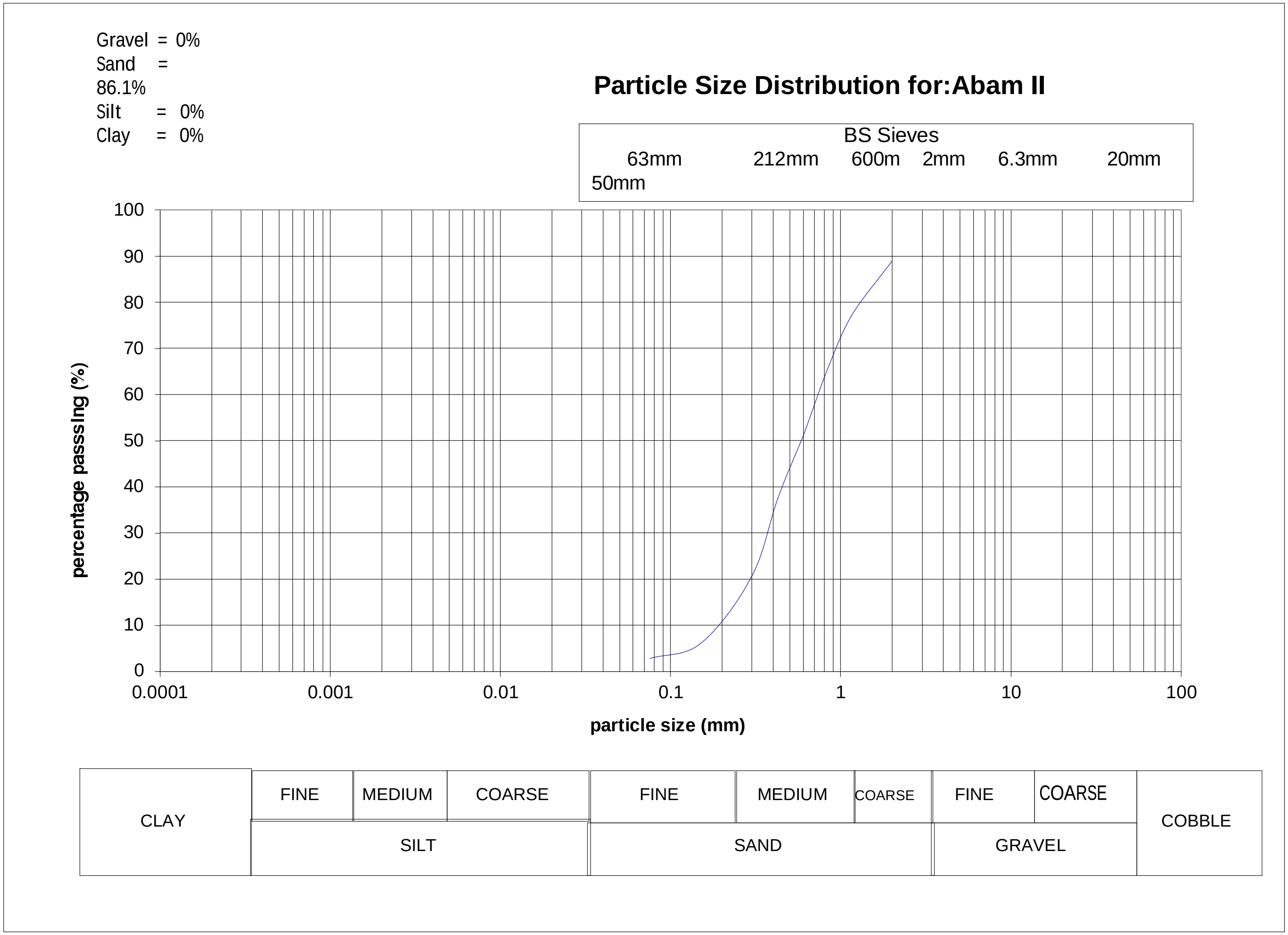
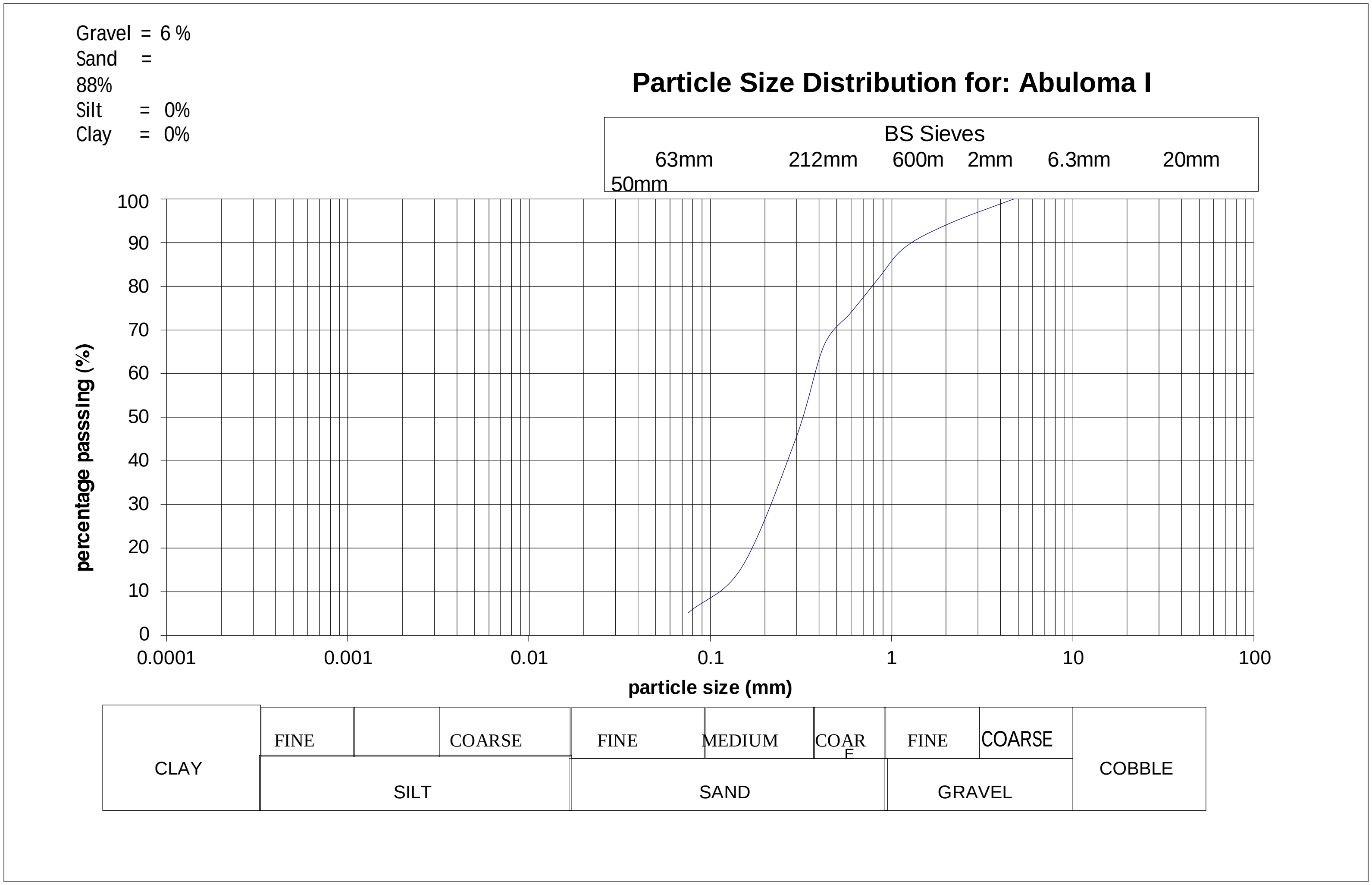


Fig 4.2 Particle Size Distribution for Abam II



COARS

Fig. 4.3 Abuloma I

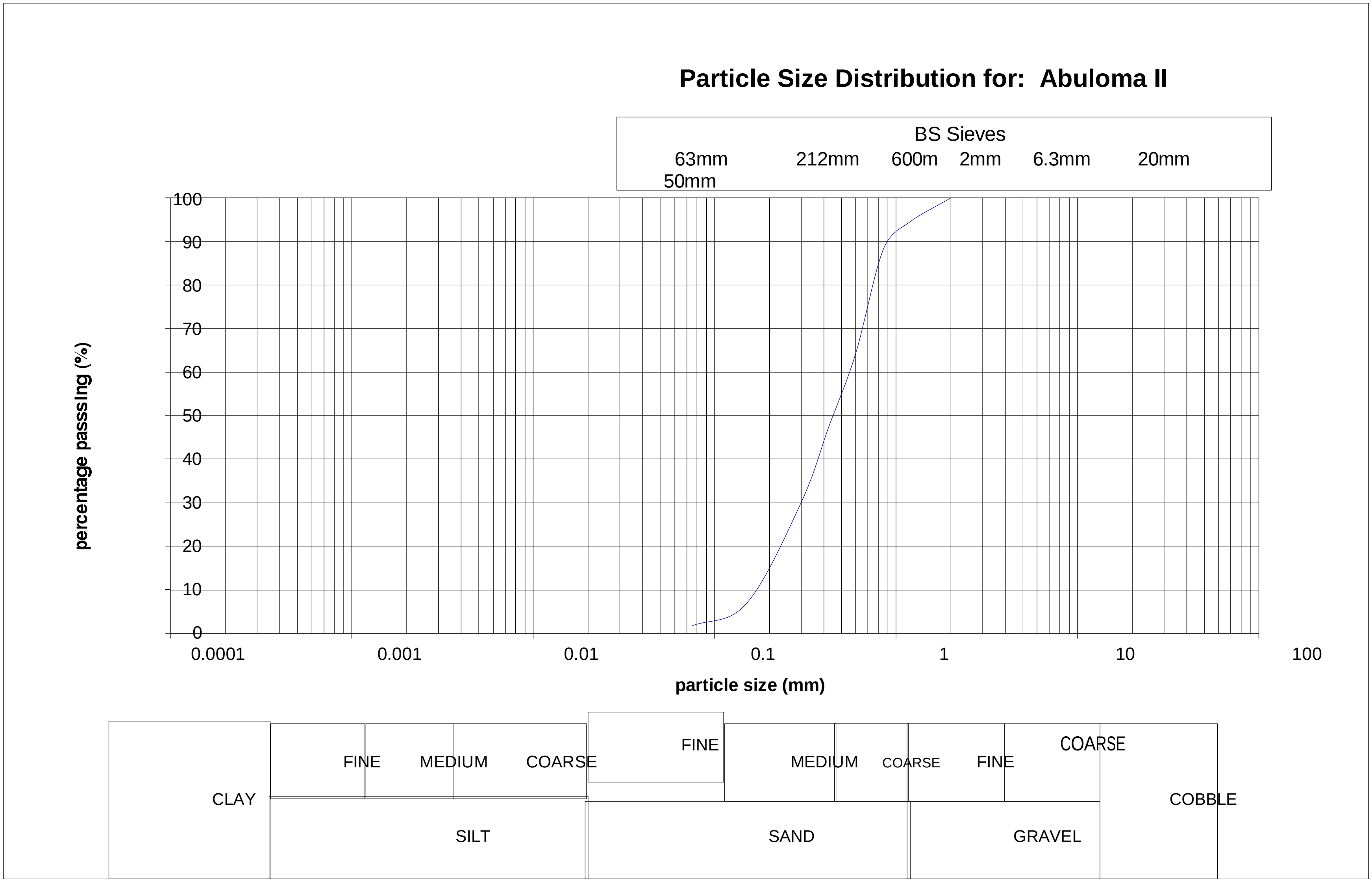


Fig 4.4.Particle Size Distribution for Abuloma II

Table 4.4Summary Soil Analysis Sample Location	Sample No.	Soil Type	Grain Size Distribution (% passing sieve)				Permeability (m/sec	Soil Consistency/ Atterberg Limits			Trans-missivity (m^3/day)
Okrika LGA			No.4 (4.75mm)	No.10 (2.00mm)	No.40 (0.42mm)	No.200 (0.075mm)		LL	PL	PI	
Abam – Refinery Road	1	Sandy/clay. Silty/Clay Soil	97.7	89.6	60.09	15.12	8.68 x 10-1	63.2	47.7	15.5	7.05 x 10 -2
APC Okrika LGA Secret.	2	Generally Sandy/Clay Sand	99.47	86.1	59.89	12.01	8.60 x 10-1	64.1	48.9	15.2	4.58 x 10-2
Abam – Ibaka Road	3	Generally Sand	100	88.0	61.14	20.84	7.68 x 10 -1	60.8	44.5	16.3	9.06 x 10 -2
Abam – Oba Waterside	4	Greyish, generally silty sand/clay soil	92.2	74.5	31.47	27.6	8.67 x 10-1	74.6	54.2	20.4	8.11 x 10 -2
Port Harcourt LGA											
Abuloma Waterside (Jetty Area)	5	Brownish Clay/sandy soil	95.7	79.6	50.09	15.12	8.68 x 10-1	63.2	47.7	15.5	7.05 x 10 -2
Okilo Road Area	6	Brownish humid soil	970	86.0	61.14	12.84	7.68 x 10 -1	60.8	44.5	16.3	9.06 x 10 -2
Ejuan/Odili Rd	7	Loamy/clay	99.47	86.1	59.89	12.01	8.60 x 10-1	64.1	48.9	15.2	4.58 x 10-2
Okuru – Abuloma Link Rd (Golf Estate)	8	Top> 0-5m Soft greyish organic clay (Generally a sandy/cla	98.2	74.5	31.47	27.6	8.88 x 10-1	79.6	54.2	20.4	8.11 x 10 -2

Table 4.4showed thatthe areas under study (Port Harcourt and Okrika) could be rationalized as underlain by at least three primary soil zones. The primary soil zones include an organic clayey layer of about 0-5m thickness, which is soft and grayish brown in color. The dark gray coloration is mostly ascribed to its rich organic content. Beneath the clay is a layer of soft grayish silty clay with variable thickness of about 7-11m, which may extend to the depth of 20m. Underlying the silty clay is a relatively clean, medium to coarse-grained, uniformly-graded sand deposit (aquiferous zone) of about 10-26m thick, which is the water bearing formation. In the clay sandy soil zone, the infiltration rate is likely to increase because of the sandy nature of the soil. Generally, active clays have high water holding capacity and are also characterized by low permeability and low resistance to shear.

The tables furthered showed that thesoil is fine-grained and highly plastic. Below this is dark grey soft film of clay and silty sands which are medium grained, loosely dense silty sand and in some section sandy clay soils. In general the area is more of sandy clay and sandy silt soil.Grain size analysis results shows that Abam 1 and 2 are poorly sorted with fines (silt/clay fractions). The coarse grained sands possess greater infiltration capacity since the number of particles per unit area is large and void spaces are greater.The permeability test result reveal a low value of 2.17×10^{-3} *cm/sec for the silty clay soil, while the sandy soils display a high range of* 7.33×10^{-1} *to* 8.67×10^{-1} *cm/sec. Infiltration capacity of the soil depends on the permeability, degree of saturation, vegetation and amount of duration of rainfall. The implication from is that sandy soil have confining layers that are unequally effective and more surface based pollutants could find their way into groundwater systems.The average transmissivity of the confining layers ranges between* 4.58×10^{-2} *and* 9.06×10^{-2} *this result is suggestive of highly transmissible aquifer indicating the possibility of leakage.*

The implication from this result becomes clear when viewed against the backdrop of the works of Amangabara and Njoku (2012) who worked on the vulnerability of groundwater as a result of the activities of artisanal refineries. In that study, the researchers were able to establish a pollution plume composed of petroleum hydrocarbon to hit the groundwater due to the porosity and permeability of the soil. Though their work was centered around Bolo in Ogu/Bolo LGA, but because but because of its proximity in both distance and latitude to Okrika and Port Harcourt City LGAs it can serve as a regional example of the possibility of porous sandy formation to transmit crude oil pollution to the groundwater causing severe hydrocarbon pollution.

When metals enter the soil, either from natural or anthropogenic sources, they are retained and can be rendered relatively immobile because of sorption reactions with the soil constituents. However, the mobility and availability of metals in soils differs depending on different sorption and desorption mechanisms. These mechanisms depend on the soil material as well as characteristics of the sorbing metal, and on pH (Alloway, 2005).In soils, which are heterogeneous systems with a range of particle sizes, porosities and multiple retention sites, metal ions are transported and sorbed by the different mechanisms simultaneously and at different rates. Metals may enter the soil either in organically complexed form or as metal salts. In the latter case, the metal cations adsorb on mineral and organic surfaces, and are more exchangeable than metals of natural origin. In general, metals from anthropogenic sources are therefore more bioaccessible than metals from natural sources (Grøn & Andersen, 2003). Soil properties and metal origin thus influence the bioaccessibility of metals by affecting their form and solubility (Ruby et al., 1996).

4.3Testing of Hypotheses

To validate the hypotheses stated at the beginning of this research work, data generated from the field and laboratory analyses were subjected to statistical analyses using the SPSS statistical package ver.17 and the results of these analyses are presented in this section.

The following hypotheses are therefore formulated for this study:

I. *There are no variation in soil characteristics between Abuloma and Abam Ama Communities*
II. *The soil in the area is not under threat of Soil pollution from industrial related activities*

4.3.1 Hypothesis one: There are no variation in the Heavy metal Characteristics of Soils in Abam Ama and Abuloma

This hypothesis was conducted to compare NESREA Soil quality standard with results obtained from analyzing Soil Samples collected from various locations in the study area to establish if there is any variation, and establish based on the finding if soil in the study area are under threat of contamination from industrial and related activities.

. The statistical tool deplored is the Analysis of variance (ANOVA) it is a collection of statistical models used to analyze the differences among group means and their associated procedures (such as "variation" among and between groups) In the ANOVA setting, the observed variance in a particular variable is partitioned into components attributable to different sources of variation. In its simplest form, ANOVA provides a statistical test of whether or not the means of several groups are equal, and therefore generalizes the t-test to more than two groups. ANOVAs are

useful for comparing (testing) three or more means (groups or variables) for statistical significance. the outcome of these tests is the acceptance or rejection of the null hypothesis (H_0). The null hypothesis generally states that: "Any differences, discrepancies, or suspiciously outlying results are purely due to randomand not systematic errors". The alternative hypothesis (H_a) states exactly the opposite.The stated hypotheses are as follows:

H_0: *There is no significant variation of Heavy metal and TPH variables between Soils in Abam Ama and Abuloma*

i.e. $m_1 = m_2$

H_a: *There is.*

4.3.2 STATISTICAL OUTPUT

Table 4.5Descriptive Statistics

	N	Range	Minimum	Maximum	Mean		Std. Deviation
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic
pH	8	.90	5.50	6.40	6.0125	.12311	.34821
Mn	8	35.03	2.76	37.79	22.4409	5.70119	16.12541
Cu	8	7.75	1.35	9.10	5.3650	.96114	2.71852
Cr	8	1.05	.06	1.11	.6600	.14760	.41748
Cd	8	2.15	.21	2.36	.9463	.29170	.82505
Pb	8	1.55	.31	1.85	1.0888	.19386	.54833
Zn	8	785.00	36.00	821.00	215.0000	98.12747	277.54639
Fe	8	419.00	139.00	558.00	382.2500	60.75353	171.83692
K	8	24.92	18.09	43.01	33.5838	3.18049	8.99578
CEC	8	2.92	2.09	5.01	3.7600	.35188	.99527
TPH	8	18873.00	1469.00	20342.00	6368.5000	2502.08572	7076.96713
Valid N (listwise)	8						

Table 4.6 Test of Homogeneity in Spatial mean variance

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Column 1	88	56316.87	639.9644	7371340
Column 2	88	396	4.5	5.310345

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	17767862	1	17767862	4.820792	0.029442	3.895458
Within Groups	6.41E+08	174	3685673			
Total	6.59E+08	175				

Table 4.5 shows the minimum. Maximum, standard error of the mean and standard deviation of all parameters considered in this study. While table 4.6 is the output of the test statistics (Test of Homogeneity in spatial mean variance). The ANOVA table indicates that F-value is 4.820792, F-crit is 3.895458 while the P-value is 0.029442

The test of variance of heavy metals, and other edaphic variables measured such as CEC and TPH at the various sampling locations in Abam Ama (Okrika) and Abuloma (Port Harcourt) using the analysis of variance (ANOVA) revealed that the parameters differed significantly in their means at P<0.05 [F (cal 4.820)> F (Crit = 3.89)] table 4.5

The graphical representation means separation using variation plots confirm the inequality in the mean of the variance (Fig 4.5 and Fig 4.6)

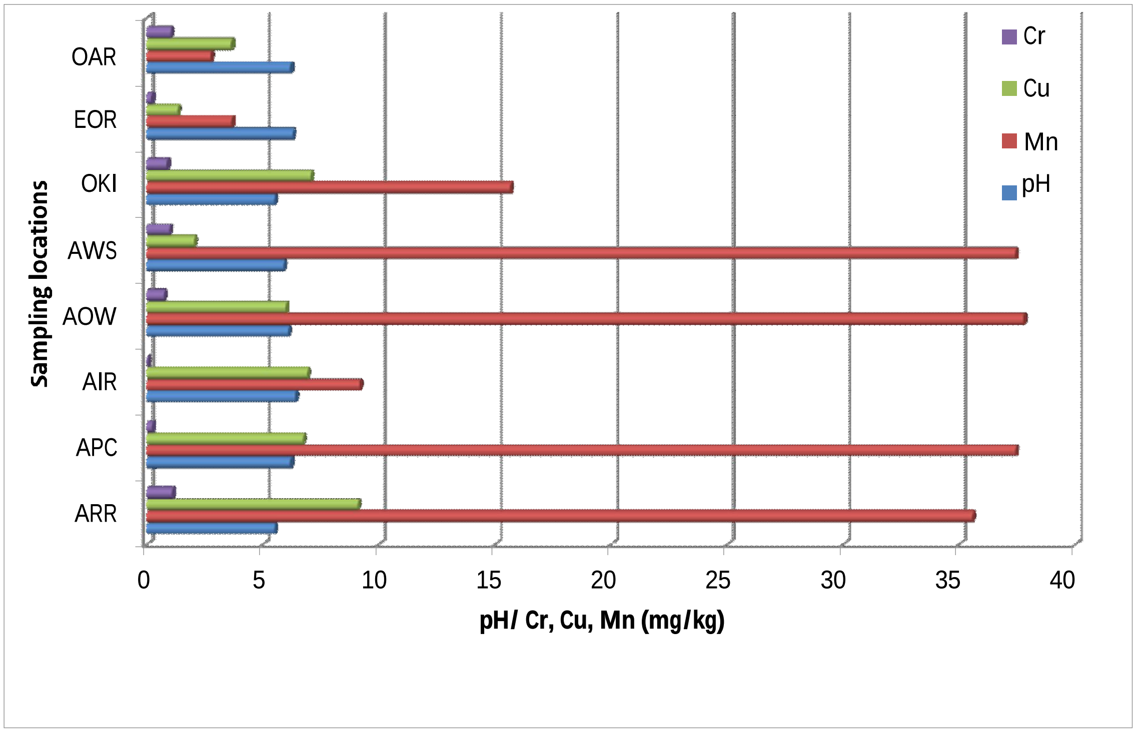


Fig 4. 5 Spatial Variation in Concentrations of heavy metals and pH in Soil samples at Abam and Abuloma

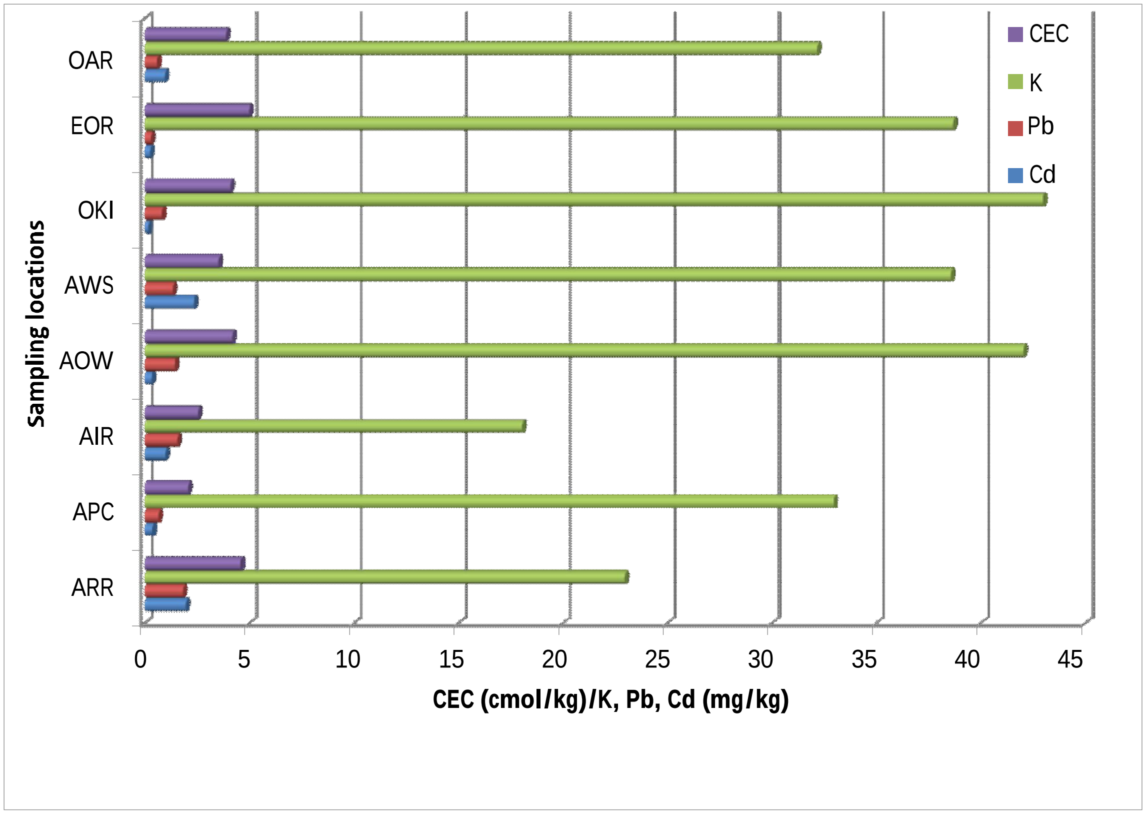


Fig 4.6 Spatial Variation in Concentration of heavy metals and cation exchange capacity in Soil samples at Abam Ama and Abuloma

4.4. Discussion

4.4.1 Heavy Metal/TPH Pollution Sources & Spatial variability

The results obtained in this study revealed that Heavy metals concentration in soil is not localized to a few areas within the study area, the heavy metals are part of the environment but when due to anthropogenic activities their concentration is elevated then the source of these contributions need to be determined and monitored. Soil is composed of finely divided rocks mixed with decayed vegetable and animal matters constituting the portion of the earth in which plants grow, the elemental composition of the soil is largely dependent on that of the rocks from which it is formed.

On the sources of some of the heavy metals such as iron, manganese, and zinc, it could be by nature for example iron.The main naturally occurring iron minerals are magnetite, hematite, goethite and siderite. The Niger Delta region experiences long duration and intensive rainfall couple with high temperature; these weather phenomena accelerate weathering of the geologic formation in the area. The weathering processes release the iron element into waters, under oxygen-poor conditions; it mainly occurs as binary iron. But under acidic and neutral, oxygen-rich conditions it becomes part of many organic and inorganic chelation complexes that are generally water soluble and the dissolved iron is mainly in the form of $Fe(OH)_2^+$ *(aq). But under acidic and neutral, oxygen-rich conditions it becomes part of many organic and inorganic chelation complexes that are generally water soluble and the dissolved iron is mainly in the form of* $Fe(OH)_2^+$ *(aq).*

Usually there is a difference between water soluble Fe^{2+} *compounds and water insoluble* Fe^{3+} *compounds. The latter are only water soluble in strongly acidic solutions, but water solubility* *increases when these are reduced to Fe* $^{2+}$*under certain conditions.Iron does not clearly alter in pure water or in dry air, but when both water and oxygen are present (moist air), iron corrodes. Its silvery colour changes to a reddish-brown, because hydrated oxides are formed. Dissolved electrolytes accelerate the reaction mechanism, which is as follows:*

$$4\ Fe + 3\ O_2 + 6\ H_2O \rightarrow 4\ Fe^{3+} + 12\ O\bar{H} \rightarrow 4\ Fe(OH)_3 \text{ or } 4\ FeO(OH) + 4\ H_2O$$

Usually the oxide layer does not protect iron from further corrosion, but is removed so more metal oxides can be formed. Electrolytes are mostly iron (II) sulphate, which forms during corrosion by atmospheric SO_2*. In sea regions (and which Abam Ama and Abuloma communities are located) atmospheric salt particles may play an important role in this process. Iron (II) hydroxide often precipitates in natural waters giving the characteristic brown colour to soils. However the entire process described above may have been accelerated by anthropogenic activities, take for example in Abuloma Area (where we have a high elevation of iron content). There is a heavy presence of marine activities ranging from ballasting to dry docking (welding and fabrication) of tug boats and other iron/aluminium coated vessels.*

The mean manganese level from the soil sample is 30.0mg/kg at Abam Ama and 83mg/kg at Abuloma. These are elevated concentrations though slight are harbingers to soil contamination. The slight increase in elevation above the recommended mg/kg could be associated with the elevated iron level and the acidic nature of the soil.

A high value of Cation Exchange Capacity (CEC) implies that the soil had a high capacity to hold cations in exchangeable form. The CEC at Abulomais higher than at Abam Ama and could be attributed to the increase of binding capacity in the soils due to oil spillage. Therefore, retention of metal ion is high in all the sampling points and this could suggest high leachability of heavy metals from soils into ground water, thereby increasing a health hazard to humans.

Hydrocarbon pollution of soil can occur in several ways, from natural seepage of hydrocarbons in areas where petroleum is found in shallow reservoirs, to accidental spillage of crude oil on the ground. Regardless of the source of contamination, once hydrocarbons come into contact with the soil, they alter its physical and chemical properties. The degree of alteration depends on the soil type, the specific composition of the hydrocarbon spilled and the quantity spilled. In the least damaging scenario, such as a small spill of a volatile hydrocarbon onto dry sand, the hydrocarbons evaporate fast, causing no chemical or physical damage to the soil. In other situations, for example a spill of heavy crude oil onto clay soil, the chemicals can remain within the soil for decades, altering its permeability, causing toxicity and lowering or destroying the quality of the soil. In such circumstances, the soil itself will become a source of pollution. Contaminated soil can affect the health of organisms through direct contact or via ingestion or inhalation of soil contaminants which have been vaporized. Soil also acts as a reservoir of residual pollution, releasing contaminants into groundwater or air over extended periods of time, often after the original source of pollution has been removed.

In the Abam Ama area, there are pockets of outposts for the supply and transfer of illegally refined crude oil with its antecedent pollution outlets. This is in addition to the constant minor spills from oil tankers (Trailers), spent oil from nearby mechanic workshops along Abam Road and those scavenged out of the atmosphere to the ground surface. In the Abuloma area, it was observed that the water fronts (from the Jetty area upto the sand filed that led off to Okilo road are *heavily industrialized especially with marine related businesses and this might also be sources of heavy metals. Repair works (drydocking) of small sea going vessels, welding and fabrication of tug boats are also finger-printed as elevation agents of heavy metals. Illegal bunkering activities (in the form of haulage/sales of locally refined fuel in drums along Abuloma- Okuru, and Between Abuloma- Ozuboko Ama axis can also be sources of these pollutions)*

On Spatial variability, there was no much variation within sampling locations in Abam and also within Abuloma but between Abam Ama and Abuloma there was significant variation of the presence of heavy metals and TPH in elevated form. Wide variation occurs because it may have been affected by weathering, soil-forming processes, climatic conditions, geochemical affinities, spillage, waste discharge, pH, redox potential, amount and kind of organic matter, mining/bunkering activity as well as aerial pollutions. In the area of study, there is a connectivity in the geological setting of the area and secondly, the area is entirely underlain by a homogenous geological formation (Benin Formation) thus, allowing water to seep through from one area to the other. When variation occurs then it is entirely as a result of anthropogenic imprint. For example, level and amount of spills that occur, activities such as iron works (welding and fabrication of tug boats/ballasting) in Abuloma area can definitely be source of variation since these activities do not take place at Abam Ama.

The pH values obtained in the study area samples may be traced to the acidity produced by organic wastes decomposing under partial reducing condition into organic acids (Richardson, 1991) and secondly, most soil sin Rivers State fall under the acidic soil classification. This scenario accelerates a lot of heavy metal reactions and accumulations. The movement and survival of microorganisms in soil and the subsurface is a highly complex issue which depends on the pathogen type, soil type and conditions, water characteristics, temperature, light availability, *the composition and viability of the indigenous microbial population, and the geographical conditions. Microorganisms move rapidly under saturated conditions, but only for a few centimeters, because microorganisms are in close contact with soil particles, promoting the adsorption of microorganisms onto the soil particles (Santamaria and Toranzos, 2003).*

All poresin soil are filled with water when soil is saturated, allowing microorganisms to pass through the soil.One of the major influences of soils is as filters, which is dependent on pore sizes and grain size (Toze, 1997). Thus, soil texture controls, in part, the movement of microorganisms, because fine grained soils avoid movement while coarse-grained soils promote it (Sinton, 1986; Abu-Ashour et al., 1994). Toze (1997) argued that the degree of adsorption is dependent on the soil composition (i.e. clay content, % of iron hydroxides present etc), the presence of organic matter, cation concentration, and pH. Organic matter present in the soil matrix tends to compete with bacterial cells and viral particles for adsorption sites and thus increases the transport of microorganisms through the soil matrix

Conclusively, Soil composition and pH influence the adsorptive ability of the soil matrix, coarse-grained (Sandy) particles material is ten times more effective in adsorbing transmitting leachate.pollution matter than fine- particle colloidal materials especially when soil pH is increased at acidic or neutral pH and little adsorption at pH values above 8

4.4.2 Pollution Threats and People at Risk in the Study Area

Abam Ama community has been exposed to legacy gas flaring from the Port Harcourt Refinery for more than forty years, and it is believed that emissions from the refinery are deposited on the soils in the community, in the same breath, Abuloma is an adjoining community with the Trans Amadi Industrial Layout which also experiences industrial pollutions from the various industries *in the area ranging from Oil Servicing Companies, marina to beverages and breweries. The results from this study so far have confirmed elevated levels of some heavy metals and petroleum hydrocarbon in the soils in the study area.Soil pH was also found to be acidic. Soil pH (acidity) is of particular importance because it controls the behaviour of metals and many other soil processes. Heavy metal cations (positively charged metal atoms) are most mobile in acid soils. This means that metal contaminants are more available for uptake by plants, or to move into the water supply thereby predisposing the people to the threat of heavy metal pollution.Since metals are largely immobile in the soil system, an accumulation occurs over time which may result in levels that are harmful to humans upon both acute and chronic exposure (Thornton, 1991; Brinkmann, 1994; Sheppard, 1998). Because of the diffuse emission in urban areas and the accumulation of soil metals with time, even residential areas located away from point pollution sources have elevated soil metal contents. The study of soils and human health is a complicated endeavour; singling out a single contaminant to study in isolation does not necessarily offer scientists a true picture of the complex relationships between contaminants, soil and health at work in real life situations*

The study further revealed that there is a burgeoning population at Abam Ama however farming have declined and the age-long fishing occupation is taking the back pew as a result of pollution. On the other hand urbanization have increased greatly at Abuloma, many green fields and vegetation have been converted to building, roads and impervious cover. However, something striking was observed in both study locations, playgrounds are still maintained. These playgrounds are bare soil bereft of vegetation and are both used by children and adult alike.

People who use this playgrounds, who farm on the relic farmlands are exposed to metal pollution. It is a common feature to see many adults taking rest especially on Saturday after a morning "work-out" in these open playgrounds, in some cases children are also seen playing in the sand in *the evening hours especially at the playground at Abam Ama and the out spaces between Abuloma and Okuru Link Road (Golf Estate) and the new Abuloma – Woji bridge. Children are more susceptible to the potential negative health effects of metals in soil than adults, both for physiological and behavioural reasons (Schütz et al.,1997; ATSDR, 2000).A study on playground soil and sand in Bergen, Norway, found elevated concentrations of As from the use of impregnated wood (Ottesen et al., 2000).*

Eating soil (geophagia) is a surprisingly widespread practice. Children under three, in particular, are very likely to eat soil while playing outdoors. As they are considered particularly sensitive to contaminants, young children are thought to be at highest risk from contaminated soils (for example, children absorb lead via their digestive system five times more efficiently than adults). Most children are exposed to metals present in soil because of their hand-to- mouth behaviour, which puts them in more frequent contact with soil than most adults. Children practise both deliberate ingestion of soil and involuntary ingestion through mouthing dirty hands and objects (ATSDR, 2000).

Children are also more susceptible than adults to any potential negative health effects of metal ingestion. While their smaller body mass increases the relative exposure to a given quantity of contaminants (per kg body mass), they also have a higher gastrointestinal absorption of metals (Schütz et al., 1997). Moreover, because their nervous system is not fully developed, they are more sensitive to neurotoxic metals such as Pb and Hg (Klaassen, 1996).

Accidental ingestion may occur in adults (for example, by eating vegetables with some soil still attached), but in some parts of the Rivers State, adults (especially pregnant women) also deliberately eat soil (izu) for a number of cultural reasons. It is commonly believed that direct ingestion is the most important pathway for human exposure to soil contamination, although other specific pathways have some importance in certain situations. However, it is difficult to conclude on which ailment is brought about by the ingestion of contaminated soil or being exposed to such soil as there are a lot of factors to consider such as duration of exposure etc. There are however reports of the impacts of heavy metal exposure to human health, the crux of this thesis is that to determine if there is exposure and which has been established. The World Health Organization (WHO) estimates that about a quarter of the diseases facing mankind today occur due to prolonged exposure to environmental pollution. Most of these environment-related diseases are however not easily detected and may be acquired during childhood and manifested later in adulthood

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Summary and Conclusion

The study was able to establish significant (P<0.05) variability between both samples of Abuloma and Abam Ama soils quality in pH, Electrical Conductivity (EC), Cation Exchange Capacity (CEC) and the concentrations of the Total Petroleum Hydrocarbon (TPH) and heavy metals. The values of the parameters obtained were higher in Abuloma than in Abam Ama soil samples. Granted that due to the nature of the underlying geology of the area, heavy metals are present but their elevated levels have been orchestrated by the various industrial activities and oil related activities in the study area like oil spillage. The natural quality of the soil ultimately changed on impact by oil spill and a significant shift in the original quality of the soil or environment might portend gradual change in soil chemistry, microbial ecology, nutrient availability, plant growth and general environmental sustainability. The heavy metals discharged by industries, traffic, municipal wastes, and hazardous waste sites as well as from fertilizers for agricultural purposes and accidental oil spillages from tankers can result in a steady rise in contamination of ground water.

In conclusion, of the eight soil samples collected and analyzed and compared with both national and international regulatory standards, significant differences were observed in terms of total petroleum hydrocarbon, manganese, and iron. Laboratory results of the water quality analyses reveals that most of the parameters analysed in the water samples were not within the acceptable quality standards and therefore indicate the existence of pollution in these soils

5.2 Recommendations

The work carried out within the context of this thesis provides evidence of the necessity of thorough soil investigations in order to correctly assess risks from soil contamination with regard people's *health. It is of course better to be safe than sorry after remediation efforts have been carried out, but generalizations and assumptions of unrealistic conditions may result in gross overestimations of risks from soil intake, with corresponding costs for society. Generalizations may also result in underestimations of risks, as has been shown by the metal analysis of the different soil particle size fractions, where the fine particles that are often ingested involuntarily had significantly higher metal contents than the original soil*

Of course, exposure routes other than direct soil intake also have to be considered in risk assessment, but it is likely that a more realistic starting point would result in more site-specific and effective remedial efforts, regardless of exposure route. Including more thorough soil analyses in risk assessment would also provide better knowledge on the behaviour of metals once ingested, since knowledge on metal behaviour in soil seems to be inadequate for accurate health risk assessment. Moreover, it seems difficult to set a generic bioaccessibility value for a specific metal, because of its varied degree of interaction with soil and gastrointestinal solution constituents. More studies on metal bioaccessibility in different types of soils and various metal contents are necessary to attain greater understanding of the risks of soil metals.

Considering the nature and geology of the study area which is predominantly sandy loam and clay soils, it is recommended continuous soil quality monitoring in on-site and off-site areas is encouraged. Increasing the frequency of sampling and analysis is also needed to effectively monitor the impact of dumpsites, particularly on environment and human health.

Government at either the State or the Local level should endeavor to construct an engineered landfill facility to reduce indiscriminate siting of refuse dumps. Sanitation levies can be charged to ensure the workability of the construction.

Stakeholders in the environment should emphasize on monitoring industrial activities and discharge of pollutants in the environment and control of soil pollution to avert possible consequences on human health and agricultural activities

To protect the health of the population it is not enough merely to check the sanitary quality of water used for human consumption, using laboratory analyses in order to obtain information such as the concentration of a certain pathogenic micro-organism or, to establish its presence or absence in the samples. Assessment of the environmental and health risk is a very vital exercise to be performed. Further research studies should be carried out to assess the environmental and health risk posed by such contamination levels observed in the soils.

References

Abii, T.A and Nwosu, P.C. (2009). The Effect of Oil- Spillage on the Soil of Eleme in Rivers State of the Niger Delta Area of Nigeria. Res J Environ Sci. 3(3):316 – 320.

Abu-Ashour J, Joy DM, Lee H, Whiteley H.R., 1994. Transport of microorganisms through soil. Water Air Soil Pollut 75:141–158

Adam, G. and Duncan, H.J. (2002). Influence of Diesel Fuel on Seed Germination. Environ. Pollut.

Agency for Toxic Substances Disease Registry (ATSDR). (1999). Toxicological Profile for Total Petroleum Hydrocarbons (TPH).US Department of Health and Human Services, Attanta, GA. USA. www.atsdr.cdc.gov/Toxprofiles/tp123-p.pdf.

Aghalino, S.O. (2000). Petroleum Exploration and the Agitation for Compensation by Oil Mineral Producing Communities in Nigeria. J. Environ. Policy Issues, 1:11

Akpofure, E. A. (2008). Oil Spillage in the Nigeria's Niger-*Delta. Psycho-morphological and Empirical Overview, International Association of Impact Assessment, Opulence Environmental Service Ltd.*

Akpokodje, E. G., (2001). Introduction to Engineering Geology. Pam Unique Publishing Coy. Ltd., Port Harcourt. 180 – 18

Amadi, P.A., Ofoegbu, C and Morrison T (1989) Hydrogeochemical Assessment of Groundwater in parts of the Niger Delta, Nigeria. Environ. Geol. Water Sci. Vol.14 No.3 pp 195 – 202

Amangabara, Gordon T and Njoku, John D(2012). Assessing Groundwater Vulnerability to the Activities of Artisanal Refining in Bolo and Environs, Ogu/Bolo Local Government Area of Rivers State; Nigeria. British Journal of Environment & Climate Change, 2(1): 28-36.

Anoliefo, G.O. and Nwosu, D.F. (1994). Effects of Spent Lubricating Oil on the Growth of Capsicum annum. L and Lyeopersicun esculentum Miller. Environ. Pollut. 88:361 – 384.

Alloway, B.J. (1994). Heavy metals in soils. Blackie & Son Ltd. Glasgow. ISBN 0-216- 92598-X. 339 pp.

Alloway, B.J. (2005). Bioavailability of elements in soil. In: Selinus, O.,Alloway, B., Centeno, J.A., Finkelman, R.B., Fuge, R., Lindh, U. & Smedley, P. (eds). Essentials of Medical Geology, Elsevier Academic Press, UK, p 347-373

Berglund, M., Lind, B., Sorensen, S. & Vahter, M. (2000). Impact of soil and dust lead on children's blood lead in contaminated areas of Sweden. Archives of Environmental Health 55, 93-97.

Bolan, N.S., Adriano, D.C. and Curtin, D. (2003). Soil acidification and liming interactions with nutrient and heavy metal transformation and bioavailability. Advances in Agronomy, 78: 215-271

Botkin, B.D. and Keller, A.D. (1998). Environmental Science: Earth as a Living Planet. 2 nd Edn., USA, John Wiley and Sons Inc.

Brassington, K., Hough, R., Paton, G., Semple, K., Risdon, G., Crossley, J., Hay, I., Askari, K. and Pollard, S.J.T. (2007). Crit Rev Env Sci Technol 37:199

Bryan, F.L., 1977. Diseases transmitted by foods contaminated by wastewater. J. Food Protect. 40 (1), 45–5

Brinkmann, R. 1994. Lead pollution in soils adjacent to homes in Tampa, Florida. Environmental Geochemistry and Health 16(2), 59-64

Bruine, M.R., Kapil, S. and Oehme, F.W. (2009). Hazardous Management Engineering, Ecotox Environ safe, 45, 198-207.

Bell-Gam W.I. (200). Major Cities and their Regions: Port Harcourt. In: Atlas of Nigeria. Les Editions, J.A. Paris, France pp138 -139

Chokor, B.A (1993). Government Policy and Environmental Protection in Developing World, Environmental Management, vol.17 No.1 pp 65-70

Cilinskis, E. and Zaloksnis, J. (1996). Solid Waste Management in the City of Riga, Latvia: Objectives and Strategy. Ambio, 25: 103 – 107

Camougis, G. (1981). Environmental Biology for Engineering. A Guide to Environmental Assessment, Academic Press, New York. pp. 10 - 16. Freeze P.A., Cherry J.A . Ground – water Practice - Hall Inc. Englewood Cliff, p. 60

Carson, J.K., Gonzalez-Quin˜ones, V., Murphy, D.V., Hinz, C., Shaw, J.A. and Gleeson, D.B. *(2010). Appl Environ Microbiol 76:3936 CEDARE.*

CIGR. (1999). Handbook of Agricultural Engineering, Vol. 1, Land and Water Engineering (Van Lier, H. N. and L. S. Pereira, Editors) pp 113 – 153.

Daniel-Kalio, L.A. and Braide, S.A. (2004). The Effect of Oil Spill on a Cultivated Wetland Area of the Niger Delta. J. Nig. Environ. Soc. 2(2); 153 – 158.

Daniel-Kalio, L.A. and Pepple, S.F. (2006). Effect of Bonny Light Crude Oil Pollution of Soil on the Growth of DayFlower (Commelina benghalensis L.) in Niger Delta, Nigeria. J. Appl. Sci. Environ. Mgt. June. 10(2), 111 – 114.

Edema, N. E.,(2006). Ionic and Physical Characteristics of the Water Soluble Fraction of Crude Oil and the Effects and Physiology of Aquatic Macrophytes. Ph.D. Thesis. University of Benin, Benin City

Ehirim, C.N. and J.O. Ebeniro, 2006. Tectonic trends delineated from drainage lineament analysis and azimuthal resistivity survey: A case study of SE Nigeria gully erosion belt. Global J. Geol. Sci., 4: 21-28.

Elis, G. (1994). Shell in Nigeria: what are the issues http://www.essentialaction.org/shell/issues.htm

EPA. (2001). Inventory of Greenhouse Gas Emissions and Sinks 1990-1999. Office of Atmospheric Programs, U.S. Environmental Protection Agency, Washington, DC; EPA 236-R-01-001. (Available on the Internet at http://www.epa.gov/globalwarming/emissions/national/download.htm).

Etu-Efeotor JO (1981). Preliminary hydrogeochemical investigations of subsurface waters in parts of the Niger Delta. J. Min. Geol., 18(1): 103 – 107.

Etu-Efeotor JO and Akpokodje EG (1990). Aquifer systems of the Niger Delta. J. Mining Geol., 26 (2): 279-284

FAO. (1993). Inland Fisheries of Africa Committee Report of the 4th Session of the Working Party on Pollution and

FEPA. (2001). Delta State Environmental Action Plan – Final Report Pp. 95

FGN (2009) Final Results of Population and Housing Census, Official Gazette 2, Volume 96 of February 2, 2009

Fierer N and Lennon JT (2011) The generation and maintenance of diversity in microbial communities. Am J Bot 98: 439–448.

Gbadegesin, A. (1997). The Impact of Oil Exploration and Production Activities on the Environment: Implications for Peasant Agriculture. A Seminar Paper on Oil and the Environment, Organized by Friedrick Elbert Foundation, Port Harcourt, pp: 14.

Gobo, A.E., Amangabara, G.T and Agobie O,I (2014) Impacts of Urban Land use changes on flood events in Warri, Delta State Nigeria.Int. Journal of Engineering Research and Applications Vol. 4, Issue 9(Version 3), pp.48-60 www.ijera.com ISSN: 2248-9622

Griffiths, B.S., and Philippot, L. (2012). Insights into the resistance and resilience of the soil microbial community. FEMS Microbiol.Rev. doi:10.1111/j.1574- 6976.2012.00343.x

Henner, P., Schiavon, M., Druelle, V. And Lichtfouse, E. (1999). Phytotoxicity of ancient gaswork soils. Effect of polycyclic aromatic hydrocarbons (PAHs) on plant germination. Organic Geochemistry-

Henry, J.G. and Heinke, G.W. (2005). Environmental Science and Engineering, 2nd ed. Prentice Hall, India, New Delhi 110001, 64 – 84.

Hernandez, L.M., Ramos, L. and Gonzalez, M.J. (1999). Sequential fractionation of Cu, Pb, Cd and Zn in soils from or near donana national park.J. Environ. Qual.,23 : 50 – 57.

Hoagland, D.R., (1972). Mineral Nutrition of Plant.Principles and Practices.John Wiley and Sons. New York. 412p

Hospers, J, (1971) Geology of the Niger Delta. In: The Geology of East Atlantic Continental Margins of Africa. Great Britain, Inst. Sci. Report 70/16. pp 121 – 142

*K*laassen, C.D. 1996. Casarett & Doull's Toxicology: The Basic Science of Poisons, 5th ed., *McGraw Hill Companies Inc. US. 1111 pp. ISBN 0-07-113927-3.*

Korade, D.L. and Fulekar, M.H. (2009). Effect of organic contaminants on seed germination of Lolium multiflorum in soil. Biology and Medicine (Bio. Med.).

Leuing, K.T., Nandakumar, K., Sreekumari, K., Lee, H. and Trevors, J.T. (2007). In: van Elsas JD, JanssonJK, Trevors J (eds) Modern soil microbiology, 2nd edn. CRC, Abington, United Kingdom, p 521

Loibner, A., Jensen, J., TerLaak, T., Celis, R. and Hartnik, T. (2006). In: Jensen J, Mesman M (eds) Ecological risk assessment of contaminated land: decision support for site specific investigations. RIVM report 711701047. Bilthoven, The Netherlands, p 19

Michael, A.M. and Ojha, T.P. (2006). Principles of Agricultural Engineering Vol. II. 5th, Edition, Jain Brothers, New Delhi, pp. 331 – 390.

Mielke H.W., Berry K.J., Mielke P.W., Powell E.T. & Gonzales C.R. 2005. Multiple metal accumulation as a factor in learning achievement within various New Orleans elementary school communities. Environmental Research 97, 67-75

Mielke, H.W. & Reagan, P.L. (1998) Soil is an important pathway of human lead exposure. Environmental Health Perspectives. 106 (Suppl 1): 217–229.

Ngah, S.A (1990). Groundwater Resource Development in the Niger Delta: Problems and Prospect. 6th International IAEC Congress

Nolan, K. (2003). Copper toxicity syndrome. Journal of Kochi.Orthomolecular Psychiatry 12: 270 – 282.

Odugwu, E.C. and Onianwa, A.T. (1987). Environmental Impact Assessment – A Case Study of Utorogu 1984 16 Delivery Line Spillage. Proc. Int Sem on Pet Ind of the Nig. Environ. pp 228 – 301.

Offodile, M .E (1991) An approach to groundwater study and development in Nigeria. Mecon Services Ltd., Jos, Nigeria. 245p

Ogbonna, D.N., Benibo, N.A and Wachukwu, C.K (2007) Bacteriological and Physico-chemical quality of borehole water from Borikiri area of Port

Harcourt, Rivers State, Nigeria. Current Trend in Biochemical Research vol. 9 (1) pp 63 -68

Ogbo, E.M. (2009). Effects of diesel fuel contamination on seed germination of four crop plants - Arachis hypogaea,Vigna unguiculata, Sorghum bicolor and Zea mays. Biotechn.

Olobaniyi, S.B and Owoyemi, F.B (2006). Characterization by Factor analysis of the chemical facie of Groundwater in the Deltaic Plain Sands aquifer of Warri, Western Niger Delta, Nigeria. African Journal of Science and Technology(AJST) Science and Engineering Series Vol.7 No.1 pp73 -81.

Omajemite, B. U. (2008). The Economic Dimensions of the Niger Delta Ethnic Conflicts: In Omotor et al (eds) Conflict Management and Peace Building in Africa. Volume II Pp. 273

Omofonmwan, S. I. and Odia, L. O. (2009). Oil exploitation and conflict in the Niger delta region of Nigeria. Journal of Human Ecology 26(1), pp25-30

Omoregie, E., Ufodike B. C, O and Onwuliri, C.O. E. (1997). Effects of water soluble fractions of oil on carbohydrate reserves of Oreochromis niloficus (L). Journal of Aquatic Science. 12:1-7.

Onuegbu, T.U., Umohand, E.T. and Onwuekwe, I.T. (2013). Physicochemical Analysis of Effluents from Jacbon Chemical Industries Limited.Int. Journal of Science and Technology. 2 (2): 169-172.

Ottesen, R.T., Volden, T., Haugland, T. & Alexander, J. 2000. Jordforurensning i Bergen – Oppfølgende undersøkelser av jordforurensning i barns lekemiljø i Sentrum-, Lakesvåg-, Løvstakken-, Sandviken og Landås bydeler. Helseriskovurderinger. NGU Rapport 2000.089. (online)

Page A.L., Lue-Hin G.C., Chang C.A., 1986. Utilization, treatment, and disposal of waste on land. In: Utilization, Treatment, and Disposal of Waste on Land (Brown K. W. et al., Editors), pp 1. SSSA, Inc. Madison, Wisconsin, USA

Perrodine, Y., Moszkowcz, P., Imyim, A., Barna, R., Rethy, Z. and Barna, L. (2002). ‘Environmental behaviour of a construction made of a mixture of hydraulic binders and *air pollution residues from Municipal Solid Waste Incineration. Part 1.Physico – chemical characterization and modeling of the source term, Waste Management 20, 741- 750.*

Prosser, J. I. (2012). Ecosystem processes and interactions in a morass of diversity. 81(3), 507–519

Robertson, S.J., McGill, W.B., Massicotte, H.B. and Rutherford. P.M. (2007). Biol Rev 82:213

Ruby, M.V., Davis, A., Schoof, R., Eberle, S. & Sellstone, C.M. (1996). Estimation of lead and arsenic bioavailability using a physiologically based extraction test. Environmental Science and Technology 39, 422-430.

Santamaria Johanna, Toranzos Gary A., 2003. Enteric pathogens and soil: a short review. Int Microbiol. 6: 5-9.

Schütz, A., Barregård, L., Sällsten, G., Wilske, J., Manay, N., Pereira, L. & Cousillas, Z.A. (1997). Blood lead in Uruguayan children and possible sources of exposure. Environmental Research 74, 17-23.

Science for Environment Policy (2012) European Commission DG Environment News Alert Service, edited by SCU, The University of the West of England, Bristol. DG ENV News Alert Issue 288, 15 June 2012. Raising the profile of soil's essential contribution to *society. http://ec.europa. eu/environment/integration/research/newsalert/pdf/288na2.pdf*

Sheppard, S.C. (1998). Geophagy: Who eats soil and where do possible contaminants go? Environmental Geology 33, 109-114.

Sinton L. W., (1986). Microbial contamination of alluvial gravel aquifers by septic tank effluent. Water Air Soil Pollut 28:407–425

Smith, M.J., Flowers, T.H., Duncan, H.J. and Alder, J. (2006). Effects of polycyclic aromatic hydrocarbons on germination and subsequent growth of grasses and legumes in freshly contaminated soil and soil with aged PAHs residues.

Stainer, R. J., Ingraham, J. L., and Painter, P. R. (1989). General Microbiology. MacMillan Education Limited, 576pp

Toze S. (1997). Microbial pathogens in wastewater, Literature Review for Urban Water Systems. Multi-divisional Research Program. CSIRO Land and Water Technical report No 1/97

Udom, G.J., Etu-Efeotor, J.O. and Esu, E.O. (1999). Hydrochemical evaluation of groundwater in parts of Port Harcourt and Tai-Eleme local government areas, RiverState. Global Jour. Pure and Appl. Sc. 5/5, 545-551.

United Nations Development Report (UNDP). (2006). Niger-Delta Development Human Report.

USEPA (2001). Current Drinking Water Standards. United States Environmental Protection Agency, Washington, DC

Vavrek, M.C. and Campbell, W.J. (2002). Contribution of seed banks to freshwater wetland vegetation recovery. Louisiana Applied and Educational Oil Spill Research and Development Program, OSRADP.

Yakowitz, H. (1988). Identifying, classifying and describing hazardous wastes: In Jacqueline, A. L. (Editor) Hazardous wastes management (Industrial and environment).Vol 2 United Nation Environmental programme.56-78.

APPENDIX 1

Rivers State Ministry of Health Diseases Surveillance Report