IMPACT OF PALM OIL MILL EFFLUENT (POME) ON PHYSICOCHEMICAL PROPERTIES OF SOIL IN UMUORGU, IMO STATE.

BY

NWAKAMMA HENRY NNAEMEKA (B.Sc, ABSU)

20114774368

A THESIS SUBMITTED TO THE
POSGRADUATE SCHOOL
FEDERAL UNIVERSITY OF TECHNOLOGY OWERRI

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR
THE AWARD OF MASTER OF SCIENCE (M.Sc) DEGREE IN
ENVIRONMENTAL TECHNOLOGY

OCTOBER, 2014.

IMPACT OF PALM OIL MILL EFFLUENT (POME) ON PHYSICOCHEMICAL PROPERTIES OF SOIL IN UMUORGU, IMO STATE.

BY

NWAKAMMA HENRY NNAEMEKA (B.Sc, ABSU)

20114774368

A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL,

FEDERAL UNIVERSITY OF TECHNOLOGY, OWERRI.

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF SCIENCE (M.Sc) DEGREE IN ENVIRONMENTAL TECHNOLOGY.

OCTOBER, 2014.

CERTIFICATION

This is to certify that this research work was carried out by **NWAKAMMA HENRY NNAEMEKA** (Reg. No; 20114774368) of the Department of Environmental Technology, School of Environmental Technology, School of Post Graduate Studies, Federal University of Technology Owerri.

………………………………………
………………………………………
Dr. P.C. Njoku   Date
(Supervisor)

………………………………
………………………………………
Dr. Emeka.E. Oguzie   Date
(Head of Department)

………………………………………
………………………………
Prof. G.N. Onuoha   Date
(Dean, School of Environmental Technology)

………………………………
………………………………………
Engr. Prof. (Mrs) K.B. Oyoh   Date
(Dean, Post Graduate Studies)

……………………….................

....

Prof. G.A. Obodo
(External Supervisor)   Date

DEDICATION

This research work is dedicated to the Glory of God Almighty for His inspiration throughout the study of my M.Sc programme.

ACKNOWLEDGEMENTS

I would like to express my deepest gratitude to my project supervisor; Dr. P.C. Njoku for his continuous supervision, guidance, motivation and support over the entire duration of my Master of Science programme in the Federal University of Technology, Owerri towards a successful completion of my thesis. I also thank in a special way Mr Leonard Mgbeahuruike for His unalloyed assistance.

I would like to thank specially the head of my department, Dr. Emeka Oguzie for making this dream a reality and I also appreciate all the staff of Environmental Technology, FUTO especially my lecturers that taught me in a special way throughout my course works, Dr. C.G. Okoli, Dr. E.E. Nkwocha, Dr. S.M.O Akhionbare, Dr. A.O Nnaji, Dr. J.D. Njoku, Dr. M.A. Nwachukwu & Dr. C.O. Nwoko, God bless you. I would thank in a special way, Mr. Henry Ogbuagu, Dr. C.E. Ihejirika, Mr. Obi I. Chinedu, and Mr. Darlington Ashiegbu for their guidance towards achieving the success of this work.

I also would like to express my sincere gratitude to my Parents, Chief & Lolo M.C Nwakamma and my siblings who always encouraged and supported me in all my difficulties.

Finally to my friends; Mr. Chibuike Onyeukwu, Rawlings Ndugbu, Chinaeme Onyenegecha, Chibuzor Manuwuba, Dozie Udumka, Izuchukwu Ikeakolam,

I thank you all.

Nwakamma H.N.
Owerri,
2014.

TABLE OF CONTENTS

CHAPTER ONE

CHAPTER TWO

CHAPTER THREE

CHAPTER FOUR

CHAPTER FIVE

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Palm oil production is increasingly regaining prominence in Nigeria as a significant agro industrial economy. However, the process results in huge amounts of palm oil mill effluent (POME). This study investigated the various physicochemical properties of Umuorgu soil as influenced by POME. Field sampling conducted at four (4) sampling points spatially located and designated as; SP1 (1m). SP2(100m), SP3(200m) and SP4(300m) at respective depths 0-15cm and 15-30cm along drainage flow path and a control soil(CS) established 1000m away from the polluted soil(PS) were studied with respect to the POME composite samples(fresh & unfresh) from an active mill. Soil and POME samples were analyzed for their parameters respectively using standard analytical methods. Application of descriptive statistics, coefficient of variation and correlation were used for data analysis. The results obtained for polluted soil (PS) and control soil(CS) as a function of the POME showed moderate variations in mineral elements of polluted site as 0.03-0.06(0.04±0.01)mg/kg of N, 10.14-16-70(13.84±2.13)mg/kg of P,0.03-0.07(0.05±1.01)mg/g of K, 0.33 4.34(1.09±1.34)mg/kg of Mg, 1.00-13.80(5.42±4.30)mg/kg of Ca and significant variations in concentrations of palm oil mill effluent(POME) on mineral elements and organic loads as 34.9(4.75-2.37)mg/dm^3 of N, 3.22(0.83-0.41)mg/dm^3 of K, 8.0(1.63-0.82)mg/dm^3 of Mg, 10.9(0.3-0.15)mg/dm^3 of Ca, 9160(955-390)mg/dm^3 of Oil & Grease, 10560(980-490)mg/dm^3 of BOD, 13775(670-335)mg/dm^3 of COD. pH was significantly reduced in the palm oil

mill effluent (pH 4.65) when compared to polluted soil and control soil (pH 6.69 &6.55) respectively. Thus, POME if well treated could be a soil enricher.

CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND OF STUDY

There is growing concern that agriculture, as fundamental as it is to the existence of man, is also responsible for many of the environmental ills facing the world today (Hansen *et al.*, 2001). Land degradation and loss of soil fertility caused by inappropriate land use is a major problem in Nigeria and other parts of the world. Agrochemicals, including chemical fertilizers and synthetic pesticides which have become an integral and indispensable component of modern agriculture, besides increasing production, are known to cause such negative side effects. These include eutrophication of fresh and marine waters, excessive nitrate leaching into ground water and the persistence of pesticide residues in food, soil and water. Similarly, processing of agricultural produce also contributes to pollution (Patricia *et al.,* 1991).

Food produce processing industries generate large quantities of effluent with a high Biochemical Oxygen Demand (BOD) which when discharged untreated into water courses and soil, adversely affects aquatic life, domestic water supply and land uses.

Oil palm cultivation and processing, like other agricultural and industrial activities, also raise environmental issues. Palm oil milling has been seen as a renowned agribusiness that brings a good return on investments. The palm oil industry contributes 83% of the single largest polluter in Malaysia, the situation is probably similar in other palm oil producing countries (Kwon *et al.,* 1989), and so raises the need to look at the effect of palm oil wastes (especially the effluent) on the environment in Nigeria.

Palm oil processing is carried out using large quantities of water in mills where oil is extracted from the palm fruits. During the extraction process, about 50% of the water results in palm oil mill effluent. It is estimated that for every 1 tonne of crude palm oil produced, 5-7.5 tonnes of water end up as palm oil mill effluent (POME) (Okwute and Isu 2009).

In major oil palm producing nations like Indonesia and Malaysia, production of crude oil results in an annual production of up to 3 billion pounds of palm oil effluent. These effluents generally contain materials which at concentrations above threshold values are injurious to the environment (Wu *et al.,* 2009), it becomes necessary that effluent water should be treated or purified before being discharged into the environment.

The process of oil palm processing in Nigeria is a routine procedure for most small scale operators. First the palm bunches are quartered (cut into parts) and left overnight for easy separation of the nuts from the spikelet. The fruits are

boiled for 1-1.5 hr, pounded in a mortar or macerated with feet in a canoe-like container; water is added and is well mixed up. All nuts are then carefully removed by hand. The fibres are well-shaken over in the sludge, until oily foams come to the surface of the sludge. The foam is collected in a container until there is no more foam formation. The collected foam is later boiled for about 30 to 40mins.The clean edible oil then collects on the surface leaving the sludge at the bottom. Sometimes the oil in the sludge pit is recovered and mixed with fibre to make a fire starting cake called flint. At other times, the sludge is poured on the surrounding bushes and soil together with the liquid waste known as palm oil effluent.

In Nigeria's palm oil mill industry, and small scale traditional operators most of the POME produced undergo little or no treatment and are usually discharged in the surrounding environment. This POME could pollute streams, rivers or surrounding land (Okwute and Isu, 2007); rivers consequently turns brown, smelly and slimy. Often fish and other aquatic organisms get killed and local people are denied of the availability of local water sources for domestic uses and fishing (Ezemonye *et al.,* 2008). Moreover, raw POME will readily cause clogging and water logging of the soil and it kills vegetation on contact, but these problems can be overcome by controlled application of small quantities at a time (Wood *et al.,* 2003). Oswal *et al.,* 2002 conducted a study on treatment of this effluent using Yarrowia lipolytica NCIM 3589, a marine hydrocarbon degrading yeast isolated from Mumbai, India and a COD reduction of about 95% with a retention time of two days was achieved. Many methods of utilizing the effluent to advantage have been tried by researchers including Davis (1978), Chan *et al,* (1980), Dolmat *et al.,*(1987),Bek-Nielsen *et al*.,(1999) and more recently, Ahmad *et al*.,(2003). These methods include tank digestion and mechanical aeration, tank digestion and facultative ponds, the decanter-drier system, aerobic and facultative ponds and distillation ponds.

In Malaysia, the enforcement of strict laws promulgated under the Environmental Quality Act was made. This led to the development of these innovative technologies for the utilization of POME.

The assessment of the possible ecological effects of effluents from palm oil mill industries on the environment through surveillance on the physico-chemical alterations caused by these discharged wastes are therefore of uttermost significance. Using Umuorgu palm oil mill as a reference point, the current study assesses the impact of palm oil processing effluent discharge on soil quality in south eastern Nigeria.

Palm oil production is one of the major socioeconomic activities of inhabitants in some areas due to the abundance of palm trees (*Elaies guineensis*) as well as other palm families, as such large quantities of palm fruit are harvested and processed weekly and most times daily; and during processing, large quantities of palm oil effluents are discharged onto the soil. This has been the practice of the people for decades, but little do the people know of the ameliorating effect of this effluent or waste on their soil.

Though, Osemwota *et al*. (2010) reported that the application of organic wastes (such as effluents, compost and sewage sludge) to soils increases plant growth; and that organic wastes contain considerable amounts of plant nutrients including micronutrients that are beneficial to plant growth. However, since POME is organic in nature, it may have tremendous effects on the supply of nutrient elements to the soil. According to Odu and Mba (1991), inorganic fertilizers supply nutrients alone whilst organic fertilizers not only supply nutrient elements through microbial assistance but also help in the improvement of soil physical properties. The characteristics of palm oil mill effluent depend on the quality of the raw material and palm oil production processes in palm oil mills (Rupani *et al.,* 2010).

1.2 STATEMENT OF THE PROBLEM

Umuorgu Palm oil mill, a subsidiary of Adapalm Nigeria Limited located at Amuzu Aboh Mbaise L.G.A, Imo State is an active oil mill with production capacity of five tonnes per hour but due to technical and environmental constraints, the plants now produces at 4 tonnes per hour.

In recent time production capacity has tremendously increased due to high demand of the produce by manufacturing industries, which in turn has generated a lot of untreated effluents discharged into the soil respectively.

Since the commencement of this mill, no proper investigation has been carried out at Umuorgu processing site. Although limited quantitative information is available on the impact of POME in soil physical and chemical properties.

It was against this background that the present study attempts to contribute to the knowledge gap by investigating and documenting evidences on the effects of POME on the soil around Umuorgu palm oil mill.

1.3 AIM AND OBJECTIVES

The aim of the study is to evaluate the impact of palm oil mill effluent (POME) discharged from Umuorgu palm oil mill of Adapalm Nigeria Limited on the physico-chemical properties of the surrounding soil with the following specific objectives;

1. To characterize soils in relation to their chemical and physical properties.
2. To determine the constituents of POME on soil quality.
3. To determine the strength of variability of POME on soil quality.
4. To compare the physicochemical concentrations with the regulatory standards.
5. To compare the constituents of POME to that of the control soil (CS).

1.4 SCOPE AND DELIMITATION

This research study investigated the physicochemical properties of palm oil mill effluent impacted soil on the farm land environment within the vicinity of Umuorgu palm oil mill in Imo State. Thus, for soil samples, the following parameters were determined; pH, Moisture Contents, Percentage Total Nitrogen (TN), Total Organic Carbon (TOC), Electrical Conductivity (EC), Phosphate, Sulphate, Soil Textural Class (Sandy, Clay, Loamy), Magnesium(Mg), Calcium, Potassium and Sodium.

Also, for palm oil mill effluent (POME) samples the following parameters; pH, Electrical Conductivity, TDS, TSS, Total Acidity, Phosphate, Sulphate, Nitrate-Nitrogen, BOD, COD, DO, Oil & Grease, Calcium, Magnesium and Potassium were determined respectively.

1.5 SIGINIFICANCE OF STUDY

The utmost importance of current study is to identify the possible ecological effects of effluents from palm oil industries in the soil. These will be measured on the bases such as:

- To ascertain the strength of POME in relation to soil quality.
- To create a solution that is protective of human health and environment and finally

- To compare the concentration of physicochemical parameters with regulatory standards.

CHAPTER TWO

2.0. LITERATURE REVIEW

2.1. MEANING OF SOIL

The definition of soil varies depending on the person considering it. Soil means different things to different people; for instance, to the farmer soil is where crops are grown. Even soil scientists may hold differing definitions, depending on their area of study.

For the purposes of this research, soil is defined as the top layer of the earth's crust. It is formed by mineral particles, organic matter, water, air and living organisms. It is in fact an extremely complex, variable and living medium. The interface between the earth, the air and the water, soil is a non-renewable resource which performs many vital functions; food and other biomass production, storage, filtration and transformation of many substances including water, carbon, and nitrogen. Soil has a role as a habitat and gene pool, serves as a platform for human activities, landscape and heritage and acts as a provider of raw materials. These functions are worthy of protection because of their socio-economic as well as environmental importance. Erosion, loss of organic matter, compaction, salinization, landslides, contamination, sealing and soil degradation is accelerating, with negative effects on human health, natural ecosystems and climate change, as well as on our economy (Soil Survey Staff, 1999 of Taxonomy, Second Edition).

2.2 GENERAL COMPOSITION OF SOIL

Mineral matter, organic matter, soil water, and soil air are the four major components of soil. The proportions of these components may vary between horizons in a soil or between similar horizons in different soils. The ratio of soil water to soil air depends upon whether the soil is wet or dry. The mineral matter composed of particles ranging in size from the sub microscopic to gravel or even rocks in some cases, accounts for the bulk of the dry weight of the soil and occupies some 40 to 60% of the soil volume. Organic matter, derived from the waste products and remains of plants and animals, occurs in largest amounts in the surface soil, but even here seldom accounts for more than 10% of the dry weight of the soil, Buol *et al*., (2003).

Soils are very porous bodies. Some 40 to 60% of the volume is inter particle space, or pore space. The pores, highly irregular in shape and size but almost all inter connected by passages, contain soil water, soil air, or both of these. The soil water reacts chemically with the soil solids and usually contains dissolved substances and perhaps suspended particles. The soil air approaches equilibrium with atmospheric air through movement of individual gases.

Bedrock is the ultimate source of the inorganic component in soils. When rock is exposed at the surface of the earth's crust, it is broken down into smaller and smaller fragments by physical forces. The fragments may be altered or decomposed by chemical reaction of mineral matter with water and air. Hundreds, thousands, or even millions of years may be required for the weathering or physical and chemical alteration of rock to produce the ultimate end products in soils. Once particles reach a sufficiently small size they can be moved by wind, water or ice when exposed at the surface. It is common, therefore, for small particles to be moved from one location to another. A single particle might occur in several different soils over a period of 100,000 years. Eventually, these particles or their decomposition products reach the ocean where they are re-deposited as marine sediments Eswaran *et al*., (2002).

The silicate group of minerals is dominant in soil systems. The terms, clay mineral and layer silicate are used almost interchangeably. The dominant chemical elements in silicate clays are oxygen, silicon, aluminium and iron. Important constituents in relatively small amounts are potassium, calcium, magnesium and sodium. Other elements occur in very small amounts in silicates. Carbonates, oxides, phosphates and sulphates are other mineral groups that occur commonly in parent materials.

2.3. SOIL PROPERTIES

2.3.1. SELECTED SOIL PHYSICAL PROPERTIES

Soils are porous and open bodies, yet they retain water. They contain mineral particles of many shapes, sizes and organic material which is colloidal (particles so small they remain suspended in water) in character. The solid particles lie in contact one with the other, but they are seldom packed as closely together as possible.

2.3.1.1. TEXTURE

Soil texture is the relative proportions of sand, silt and clay in a soil (Foth, 1990). Brady and Weil (1999) stated that the knowledge of the proportions of different sized particles in a soil (that is, the soil texture) is critical for understanding soil behaviour and management and that when investigating soils on a site, the texture of various soil horizons is often the first and most important property to determine. They stated furthermore that the texture of soil in the field is not readily subject to change, so it is considered a basic property of a soil.

According to Foth (1990), soil separates are the size groups of mineral particles less than 2 millimetres (mm) in diameter or the size groups that are smaller than gravel. The size ranges for these separates are not purely arbitrary, but reflect major changes in how the particles behave and in the physical properties they impart of soils (Brady and Weil, 1999). When particle size decreases, specific surface area and related properties increase greatly. Fine colloidal clay has about 10, 000 times as much surface area as the same weight of medium sized sand. Soil texture influence many other soil properties in far-reaching ways as a result of five fundamental surface phenomena as stated by Brady and Weil (1999).

2.3.1.2. STRUCTURE

Anyone who has ever made a mud ball knows that soil particles have a tendency to stick together. Attempts to make mud balls out of pure sand can be frustrating experiences because sand particles do not cohere (stick together) as do the finer clay particles. The nature of the arrangement of primary particles into naturally formed secondary particles, called aggregates, is soil structure.

The term soil structure relates to the arrangement of primary soil particles into groupings called aggregates or peds. The pattern of pores and peds defined by soil structure greatly influences water movement, heat transfer, aeration and porosity in soils. Activities such as timber harvesting, grazing, tillage, trafficking, drainage, liming and manuring impact soils largely through their effect on soil structure, especially in the surface horizons (Brady and Weil, 1999). Wetting and drying, root and animal activity, organic wastes and mechanical agitation are involved in the rearranging of particles in soils including destruction of some aggregates and the bringing together of particles into new aggregate groupings. Organic matter especially microbial cells and waste products act to cement aggregates and thus to increase their strength (Raymond and Roy, 1992).

2.3.1.3. DENSITY

Density is the weight per unit volume of an object. Soil particle density Pd is defined as the mass per unit volume of soil solid (in contrast to the volume of the soil, which would also include spaces between particles). Particle density is essentially the same as the specific gravity of a solid substance. The chemical composition and crystal structure of a mineral determines its particles density. Particle density is not affected by pore space, and therefore is not related to particle size or to the arrangement of particles (Brady and Weil, 1999).

Bulk density is defined as the mass of a unit volume of dry soil. This volume includes both solids and pores. Soils with a high proportion of pore space to solids have lower bulk densities than those that are more compact and have less pore space (Brady and Weil, 1999). According to them, any factor that influences soil pore space will affect bulk density. Fine-textured soils such as silt loams, clays and clay loams generally have lower bulk densities than do sandy soils. This is true because the solid particles of the fine-textured soils tend to be organized in porous granules, especially if adequate organic matter is present. In these aggregated soils, pores exist both between and within the granules. This condition assures high total pore space and a low bulk density. Deeper in the soil profile, bulk densities are generally higher, probably as a result lower organic matter contents, less aggregation, fewer roots and compaction caused by the weight of the overlying layers. High bulk density may occur as a natural soil profile feature (for example, a fragipan), or it may be an indication of human induced soil compaction. In any case, root growth is inhibited by excessively dense soil for a number of reasons, including the soil's resistance to penetration, poor aeration, slow movement of nutrients and water, and the build-up of toxic gases and root exudates (Brady and Weil, 1999).

2.3.1.4. POROSITY

According to Hillel (1982) and Donahue *et al.,* (1990), porosity is defined as an index of the relative pore volume of the soil or the volume of total pore spaces. It is a function of texture, structure, air and moisture content of the soil. It depends on the size, shape and arrangement, orientation of the peds (Foth, 1990). Coarse textured soils are less porous than fine textured soils. This means that the total pore space in a sandy soil may be low but a great proportion of it is composed of large pores that are very efficient in the movement of water and air. Thus the percentage of volume occupied by small pores in sandy soil is low which account for their low water holding capacity. In clayey soils, the porosity is highly variable as the soil alternatively swells, shrinks, aggregates, disperses, compacts and cracks.

2.3.1.5. CONSISTENCY

Consistence is a description of a soil's physical condition at various moisture contents as evidenced by the behaviour of the soil to mechanical stress or manipulation. Descriptive adjectives such as hard, loose, friable, firm, plastic, and sticky are used for consistence. Soil consistence is of fundamental importance to the engineer who must move the material or compact it efficiently. The consistence of a soil is determined to a large extent by the texture of the soil, but is related also to other properties such as content of organic matter and type of clay minerals.

Consistency is measured at three moisture conditions: air-dry, moist and wet. The measures of consistency border on subjective as they employ the "feel" of the soil in those states. A soil's resistance to fragmentation and crumbling is assessed in the dry state by rubbing the sample. Its resistance to shearing forces is assessed in the moist state by thumb and finger pressure. Finally, a soil's plasticity is measured in the wet state by moulding with the hand.

Hillel (1982) stated that moisture content is the variable amount of water contained in a unit mass or volume of soil. Numerous soil properties depend very strongly upon water content such as consistency, plasticity, soil strength and compatibility. Brady and Weil (1999) reviewed methods of improving the moisture content of a soil and came out that the best method is the by the use of organic matter and compost addition either as a surface mulch or by incorporation into the top layer of the soil.

2.3.1.6. RESISTIVITY

Soil resistivity is a measure of a soil's ability to retard the conduction of an electric current. The electrical resistivity of soil can affect the rate of galvanic corrosion of metallic structures in contact with the soil. Higher moisture content or increased electrolyte concentration can lower resistivity and increase conductivity, thereby increasing the rate of corrosion. Soil resistivity values typically range from about 2 to 1000 Ω m, but more extreme values are not unusual (R.J Edwards, 1998).

2.3.1.7. COLOUR

Soil colour is often the first impression one has when viewing soil. Striking colours and contrasting patterns are especially noticeable.

In most cases, colour is determined by organic matter content, drainage conditions, and the degree of oxidation. Soil colour, while easily discerned, has little use in predicting soil characteristics Donahue *et al.,* (1977).

It is of use in distinguishing boundaries within a soil profile, determining the origin of a soil's parent material, as an indication of wetness and waterlogged conditions, and as a qualitative means of measuring organic, salt and carbonate contents of soils. Soil colour is primarily influenced by soil mineralogy. Many soil colours are due to various iron minerals. The development and distribution of colour in a soil profile result from chemical and biological weathering, especially redox reactions. As the primary minerals in soil parent material weather, the elements combine into new and colourful compounds. Iron forms secondary minerals of a yellow or red colour, organic matter decomposes into black and brown compounds, and manganese, sulphur and nitrogen can form black mineral deposits. These pigments can produce various colour patterns within a soil. Aerobic conditions produce uniform or gradual colour changes, while reducing environments (anaerobic) result in rapid colour flow with complex, mottled patterns and points of colour concentration(The colour of soil, United States dept of Agriculture, Natural resources conservation services).

2.3.2. SELECTED SOIL CHEMICAL PROPERTIES

Soil organic matter (SOM) is composed mainly of Carbon, Hydrogen, Oxygen, Nitrogen and smaller quantities of sulphur and other elements. The organic fraction serves as a reservoir for the plant essential nutrients-nitrogen, phosphorous and sulphur; increases soil water holding and Cation Exchange Capacities (CEC) and enhance soil aggregation and structure (Raymond and Roy, 1992). Because humus has a Cation Exchange Capacity (CEC) 2 to 3 times as great (per kg) as that of the various types of clay minerals, it generally accounts for 50 to 90% of the cation adsorbing power of minerals surface soils (Brady and Weil, 1999). Through its cation exchange capacity and acid and base functional groups, organic matter also provides much of the pH buffering capacity in soil (Brady and Weil, 1999).

2.3.2.1. CATION EXCHANGE

Cation exchange is the interchange between a cation solution and another cation on the surface of any negatively charged material such as clay colloid or organic colloid. A dynamic equilibrium exists between the adsorbed cation and those in soil solution. The cation exchange capacity of soils (CEC) is defined as the sum of positive (+) charges of the adsorbed cations that a soil can adsorb at a specific pH (Foth, 1990). This is expressed in Milliequivalent per 100 grams of oven dry soil. Organic colloids exhibit much greater cation exchange capacity than silicate clays. Various clays also exhibit different exchange capacities. Thus, cation exchange capacity of soils is dependent upon both organic matter content and type of silicate clays. Cation exchange capacity is an important phenomenon for 2 reasons: (1) Exchangeable cations such as Ca, Mg and K are readily available for plant uptake (2) Cations adsorbed to exchange sites are more resistant to leaching or downward movement in soils with water (Miller *et al.,* 1990). Movement of cations below the rooting depth of plant is associated with weathering of soils. Greater cation exchange capacities help decrease these losses. Pesticides or organics with positively charged functional groups are also attracted to cation exchange sites and may be removed from the soil solution, making them less subject to loss and potential pollution (Miller *et al.,* 1990). The energy of retention of cations on negatively charged exchange site varies with the particular cation. The order of retention is aluminium > Calcium > Magnesium> Potassium > Sodium > Hydrogen. Cations with increasing positive charge and decreasing hydrated size are most tightly held (Raymond and Roy, 1992). The percentage of the cation exchange capacity occupied by basic cations is called percentage base saturation. The greater the percentage base saturation, the higher the soil pH (Foth, 1990).

2.3.2.2. SOIL pH

The pH is a term got from, the French word pouvoir hydrogen which means “hydrogen power”. The soil pH is probably the most commonly measured soil chemical property and is also one of the more informative (Raymond and Roy, 1992). The pH is the negative logarithm of the hydrogen ion activity (Foth, 1990). Since pH (the negative log of the hydrogen ion activity in solution) is an inverse or negative function, soil pH decreases as hydrogen ion or acidity decreases. The pH of a soil is one of the most important properties involved in plant growth. There are many soil pH relationships, including those of ion exchange capacity and nutrient availability. For example, iron compounds decrease in solubility with increasing pH, resulting in many instances where a high soil pH (soil alkalinity) causes iron deficiency for plant growth (Foth, 1990). Soil pH affects the quantity, activity and types of micro organisms in soils which in turn influence decomposition of crop residues, manure sludge and other organics.

2.4. THE SOIL ENVIRONMENT

The principal environmental variables affecting life in soils include moisture, temperature, pH, aeration (i.e. presence or absence of sufficient oxygen), organic matter, and inorganic nutrients such as nitrogen and phosphorus. The balance of these factors controls the abundance and activities of the microbes and larger animals in soils which in turn have a marked influence on the critical processes of soil aggregation and degradation of plant and animal residues and the nutrient cycling that accompanies this latter process (Soil Survey Staff, 1999 of Taxonomy, Second Edition).

To understand life in the soil, the soil is best viewed as an extremely heterogeneous collection of microhabitats. The soil is a matrix of solids including sand, silt, clay, and organic matter particles as well as aggregates of various sizes formed from them, and pore space, which may be filled with air or water. Thus, depending on the mix of environmental variables, prevailing conditions can vary quite markedly over distances on the order of a few millimetres (1 inch = 25.4 millimetres).

2.5. **GENERATION OF WASTE IN PALM OIL MILLS**

2.5.1. LIQUID AND SOLID WASTES

During the process of oil extraction, huge quantities of waste are produced in the palm oil mill, which contains liquid and solid respectively. The liquid wastes commonly referred as palm oil mill effluent (POME) is generated mainly from oil extraction, washing and cleaning processes in the mill and these contains cellulosic material, fat, oil and grease etc (Agamuthu. P., 1995).

It is the liquid waste called palm oil effluent (POME) that is usually discharged into the environment, either raw or treated (Okwute and Isu, 2007). During the extraction of crude palm oil from the fresh fruits, about 50% of the water results in palm oil mill effluent (POME). It is estimated that for 1 tonne of crude palm oil produced, 5-7.5 tonnes of water end up as POME (Ahmad *et al,.* 2003).

Palm oil mill effluent also contains significant amounts of solids, both suspended solids and total dissolved solids in the range of 18,000 mg/*l* and

40,000 mg/*l* respectively (Table 2). These solids are commonly known as palm oil mill sludge (POMS).

The solid waste that are produced in the process of extraction are the leaves, trunk, decanter cake, empty fruit bunches (EFB), palm shells and palm fibre from the mesocarp. In both traditional and modern milling settings, these solid waste products are all put to economically useful purpose such as fuel material and mulch in agriculture (despite their high C/N ratio) (Okwute and Isu, 2007). Each ton of fresh fruit bunches at the extraction mill generates approximately 0.22 tons of empty fruit bunches (EFB) (Torres *et al.,* 1999).

It is critical to examine properly what is added to the soil (that is, wastes) since according to Brady and Weil, 1999; soil genesis is brought about by a series of specific changes that can be grouped into four broad processes: Transformations, Translocations, Additions, and Losses. This leads to the discussion of the “chemical nature of palm oil mill wastes”.

2.6. CHEMICAL NATURE OF PALM OIL WASTES

2.6.1 EMPTY FRUIT BUNCH AND PALM FIBRE

The empty fruit bunch and fibre are solid waste products of the palm oil milling process and has a high moisture content of approximately 0.55-0.65% and high silica content from 25% of the total palm fruit bunch (Wambeck. N, 1999). The solid wastes contain potentially valuable nutrients, such as nitrogen and phosphorus (Wambeck.N, 1999; unilever.com). Empty fruit bunch (EFB) increased soil potassium, phosphorus and pH, improved soil structure and produced higher midday relative water content and abaxial stomatal conductance (Ortiz *et al.,* 1992).

2.6.2 PALM OIL MILL EFFLUENT (POME)

The extraction of crude palm oil from FFB requires enormous amounts of water. It has been estimated that 5-7.5 tonnes of water is required for the production of 1tonne crude palm oil and more than 50% of the water ends up as palm oil mill effluent (POME) [Ahmad et al 2003].

Sethupathi S., 2004 has categorized three major processing operations responsible for producing the POME. Sterilization of FFB, clarification of extracted CPO, hydro cyclone separation of cracked mixture of kernel and shell. Hydro cyclone contributes about 36, 60 and 4% of POME respectively in the mills. Based on palm oil production in 2005 (14.8 million tonnes), Lorestani A.A.Z. (2006) estimated that in Malaysia about 53 million m3 POME is being produced every year. Yacob *et al* (2006) estimated that about 0.5- 0.75 tonnes of POME will be discharged from mill for every tonne of fresh fruit bunch.

Wastewater composition depends mainly on the season, raw matter quality and the particular operations being conducted at any given time. Generally palm oil mill wastewater is low in pH because of the organic acids produced in the fermentation process, ranging about 4-5. Wastewater includes dissolved constituents such as high concentration of protein, carbohydrate, nitrogenous compounds, lipids and minerals, which may be converted into useful materials using microbial processes. The effluents from palm oil mill may lead to considerable environmental problems, if discharged untreated (Singh *et al.,* 2010). Therefore, the challenge of converting POME into an environmental friendly waste requires an efficient treatment and effective disposal technique.

2.6.2.1. PALM OIL MILL EFFLUENT TREATMENT TECHNOLOGIES

Land application of palm oil mill effluent (POME) is one of the disposal alternatives. Discharging the POME on the land results in clogging and water logging of the soil and kills the vegetation on contact. However, Wood *et al.*1979 reported that these problems could be overcome by the controlled application of small quantities of POME at a time. The cheapest way of discharging of POME is to release it into the river, since POME is a non toxic oily waste. But discharge of effluent into water bodies cause water depletion and results in aquatic pollution (Hwang *et al.*, 1978).

Therefore, these problems make it essential to study the effect different types of treatments on POME quality and environment. Several researchers have studied the various aspects of palm oil mill effluent treatment (Ahmad *et al.,* 2000).

Physical pre-treatment of POME consist of stages such as screening, sedimentation and oil removal prior to the secondary treatment in biological treatment system. According to Hojjat and Salleh, (2009) the combination of two processes of acidification pond and flocculation treatment is a developed pre-treatment process. Hojjat and Salleh, (2009) showed that both centrifugation and coagulation gave different pre-treatment quality which was reported to be better than that of pre-treatment by filtration method. Apart from this process, different chemicals are used in flocculation such as alum, aluminium chlorohydrate, aluminium sulphate etc. There are some natural products such as chitosan (poly D- glucosamine) that have been used in flocculation. Chitosan is a natural organic polyelectrolyte of high molecular weight and charge density; obtained from deacetylation of chitin. As the suspended solids in POME are mainly associated with its organic matter, therefore chitosan can effectively remove most of the colloidal and suspended organic matter contents, but is less efficient in removing of dissolved organic matter (Nawawi *et al.,* 2008). Solvent extraction method was used by Hameed *et al*. (2003) for removal of residual oil from POME as a pre-treatment process. Hameed *et al*. (2003) reported that the percentage extraction of oil from POME increased with the increase of mixing time, solvent/feed ratio and mixing rate for all solvents.

According to Perez *et al.* (2001) anaerobic process is a suitable treatment method due to the organic characteristic of POME. Therefore ponding system is the most conventional method for treating POME (Sulaiman, A., 2010). The pond systems have been applied in Malaysia for POME treatment since 1982 and they are classified as waste stabilization pond (Onyia *et al.,* 2001). More than 85% of palm oil mills exclusively use ponding systems due to their low costs (Zahrim *et al.*, 2009). Ponding systems are easy operating systems but they have some disadvantages such as occupying a vast amount of land mass, relatively long hydraulic retention time (HRT) of 45-60 d for the effective performance, bad odour and difficulty in maintaining the liquor distribution and biogas collection which results harmful effect on the environment (Onyia *et al* ,.2001). In the oil palm mill, the ponding system of POME treatment is the main source of environment pollution. Huge amount of the strong green house gas methane with the biogas is emitted by the anaerobic ponds and the effluent of the ponds holds the nutrients accountable for surface and ground water pollution. Every ton of crude palm oil produced is responsible for the emission of 46 m3 (32.9 kg) of methane, corresponding 384 m3 (756 kg) CO2 equivalent (Schuchardt *et al.,* 2007).

There is a possibility of improvement of POME treatment by other processes such as aerobic and anaerobic digestions, physicochemical treatments and membrane filtration (*Mohammad et al., 2009*). The organic substance of POME is generally biodegradable; therefore treatment by biodegradable process could be suitable, which are based on anaerobic, aerobic and facultative processes (Sethupathi, S. 2004). Anaerobic process or biological treatment has considerable advantages over other processes such as less energy demands, minimum sludge formation, no unpleasant odour and production of methane due to efficient break down of organic substances by anaerobic bacteria (Rincon *et al* .,2006). According to Linke, B., 2006 the anaerobic digestion process has great potential for rapid disintegration of organic matter to generate biogas that can be used in electricity generation and save fossil energy.

However, such biological practices are only applicable in the palm oil mills which acquire large area of lands (Quah *et al.,* 1982). According to Ahmad *et al*. (2005) the treatment process that is based mainly on biological treatment is quite inefficient in treatment of POME, which may lead to several environmental pollution issues. This is largely due to the high BOD load and low pH of POME, together with the colloidal nature of the suspended solids, which renders POME treatments by environmental methods difficult (Stanton, W.R., 1974).

Several researchers have used the composting technology for managing the liquid waste coming from agro industries. In order to attain adequate physical conditions for the earthworms' life and growth, the liquid waste coming from agro industries are required to be blended with ligno-cellulosic material (Macci *et al.,* 2009).

Macci *et al.* (2009) carried out vermicomposting of olive oil mill wastewaters (OOMW) by absorbing them onligno-cellulosic solid matrix. According to Macci *et al*. (2009) the vermicomposting process could be an alternative and suitable technology for the management of OOMW. Even though olive oil mill wastewaters are resistant to biological degradation, the joint action of earthworms and micro-organisms enhances its biodegradability and transformation into a non-toxic and value-added product that is useful for agricultural purposes.

This new approach can be used for the management of POME using the ligno-cellulosic material like empty fruit bunch (EFB), EFB fibre generated in huge amount during the process of extraction of palm oil from oil palm fruit. With in Malaysia, the Oil palm waste constitutes 94% of lignocellulosic material (Rosnah *et al*., 2010).

2.6.2.2. CHARACTERISTICS OF PALM OIL MILL EFFLUENT

Fresh POME is a hot, acidic (pH 4-5), brownish colloidal suspension containing high concentrations of organic matter, high amounts of total solids (40,500 mg *lg*1), oil and grease (4,000 mg *lg*1) COD (50,000 mg *lg*1) and BOD,(25,000 mg *lg1*) (Ma, A.N., 2000).

The raw or partially treated POME has an extremely high content of degradable organic matter, which is due in part to the presence of unrecovered palm oil (Ahmad *et al.,* 2003). Untreated POME contains high concentrations of free fatty acids, starches, proteins and plant tissues (Bek-Nielsen *et al.,* 1999) and as no chemicals are added during the oil extraction process, POME is considered as non toxic, but it is identified as a major source of aquatic pollution by depleting dissolved oxygen when discharged untreated into the water bodies (Khalid and Mustafa, 1992).

However it also contains substantial amounts of N, P, K, Mg and Ca (Muhrizal *et al*., 2006 and Habib *et al.,* 1997), which are the vital nutrient elements for plant growth. Due to the non toxic nature and fertilizing properties, POME can be used as fertilizer or animal feed substitute in terms of providing sufficient mineral requirements. Muhrizal *et al*. (2006) reported that POME contains high content of Al as compared to chicken manure and composted sawdust. According to Habib et al 1997, toxic metals such as Pb can also be focused in POME, but their concentrations are usually below sub lethal levels (>17.5 µg /g) (James *et al*., 1996). According to James *et al*. (1996) Pb is found in POME as a result of contamination from plastic and metal pipes, tanks and containers where Pb is widely used in paints and glazing materials.

The constituents of raw POME have been reported to be a colloidal suspension of 95-96% water, 0.6-0.7% oil and 4-5% total solids including 2-4% suspended solids (Ahmad *et al.,* 2003). Raw POME has Biological Oxygen Demand (BOD) values averaging around 25, 000 mg/litre, making about 100 times more polluting than domestic sewage (Macheswaran and Singam, 1977).

Palm oil mill effluent (POME), from a factory site in India contained about 250, 000 mg/liter Chemical Oxygen Demand (COD), 11 000 mg/litre Biological Oxygen Demand, 65mg/litre Total Dissolved Solutes (TDS) and 9, 000mg/litre of chloroform soluble material (Oswal, *et al.,* 2002).

Due to the presence of some unrecovered palm oil in the POME as reported by Ahmad *et al. (*2003), it becomes necessary to look at the chemistry and processing of palm oil.

2.7. CHEMISTRY AND PROCESSING OF PALM OIL

Palm oil and palm kernel oil are composed of fatty acids, esterified with glycerol just like any ordinary fat. Both are high in saturated fatty acids, about 50% and 80% respectively. The predominant portion of all commercial vegetable oils is a mixture of triacylglycerols (Gerhard *et al.,* 1989). The oil palm gives its name to the 16 carbon saturated fatty acid-palmitic acid found in

Palm oil, monosaturated oleic acid is also a constituent of Palm oil while palm kernel oil contains lauric acid.

The approximate concentration of fatty acids (FAs) in palm oil is as follows:

Table 2.1: Fatty Acid Content of Palm Oil

Type of fatty acid	Percentage
Palmitic C_{16}	44.3%
Stearic C_{18}	4.6%
Myristic C_{14}	1.0%
Oleic C_{18}	38.7%
Linoleic C_{18}	10.5%
Other/unknown	0.9%

(Source: Catharin *et al.,* 1999)

Fatty acids are saturated and unsaturated aliphatic carboxylic acid with carbon chain length in the range of C_6 up to C_{24}. An example of a fatty acid is palmitic acid, CH_3-$(CH_2)_{14}$ –C00H.

Splitting of oils and fats by hydrolysis, or under basic conditions saponification, yields fatty acids, with glycerin (glycerol) as a by-product. The split-off fatty acids are a mixture of fatty acids ranging from C_6 to C_{18} depending on the type of oil/fat (Faessler, 2004). Palm oil products are made using milling and refining processes; first using fractionation, with crystallization and separation process to obtain a solid stearin, and liquid olefin. By melting and degumming, impurities can be removed and then the oil filtered and bleached.

Next, physical refining removes odours and colouration, to produce refined bleached deodorized palm oil or RBDPO, and free pure fatty acids, used as an important raw material in the manufacture of other materials, example, soap (Agungjaya, 2007). In the local setting, sometimes the oil in the sludge pit is recovered and mixed with fibre to make a fire starting cake called flint. At other times, the sludge is poured onto the surrounding bushes and soil together with the liquid waste (POME) (Okwute and Isu, 2007). This, no doubt, has effects on soil properties and surrounding environment when discharged with little or no treatment.

2.8. INFLUENCE OF PALM OIL MILL EFFLUENT (POME) ON SOIL PROPERTIES

Palm oil mill wastes, especially POME, affect so many soil properties and processes by mere looking at the result of the findings from many other researchers. Often one effect leads to another, so that a complex chain of multiple pros and cons result from the addition of palm oil effluent to soils.

Irrespective of how effective the system of oil recaptured from the sludge may be; the POME discharged from an oil mill is objectionable and could pollute streams, rivers or surrounding land (Hartley, 1988). The first impression that could be got from the POME soil environment was that of bareness and a wasted land (Okwute and Isu, 2007). Raw POME will readily cause clogging and water-logging of the soil and it kills vegetation on contact (Chan *et al.,* 1990; Wood *et al.,* 2003). POME is non-toxic and bio-degradable (Hemming, 1977; Bek-Nielsen *et al.,* 1999). The application of empty fruit bunch (EFB) has been practiced as a mulch in oil palm field nurseries (Gunn *et al.,* 1961) and has shown beneficial effects on oil palm growth and yield increases in mature plants under different soil and rainfall regimes in Malaysia (Loong *et al.,* 1987; Chan *et al.,* 1980; Singh *et al.,* 2010; and Khoo and Chew, 1979). The beneficial effects of the palm shell when used as mulch is mainly due to better weed control and avoiding soil surface crusting.

It has been reported that when raw POME is discharged, the pH is acidic (Hemming, 1977) but seems to gradually increase to alkaline as biodegradation takes place. A study conducted by Okwute and Isu (2007) showed that a non-POME soil (control) is acidic (pH=3.57) and supported plant growth, the POME soil was near basic (pH =6.59) and did not support any evident plant growth. Factors such as water, unrecovered oil and cellulose fruit debris (higher organic matter) present in POME dumpsites were reported by Bek-Nielsen *et al.,* (1999) as the reason why the POME soil retained more water. Higher organic carbon and increased nitrogen content has been observed in POME soil (Wood, 1977; Huan, 1987; Dolmat *et al.,* 1987; Acea and carballas, 1996; and Okwute and Isu, 2007). The higher organic carbon value for the POME soil can be related to the constituents of raw and untreated POME. Okwute and Isu (2007) reported that the CEC values along with exchangeable cations was significantly higher in the POME than the non- POME soil. Lim and P'ng (1983) also recorded increase in pH, potassium, calcium, magnesium and organic matter content with the application of POME to soil.

Application of palm oil mill effluent (POME) could cause clogging of soil pores and hence water logging of the soil (Chan *et al.,* 1980). The first result of an oil spill is the displacement of soil air and creation of an anaerobic soil (Foth, 1990) and these restrict micro organisms and their activities by preventing oxygen movement into and through the soil in sufficient quantity to meet the oxygen demand of the organisms (Paul and Clarke, 1989). In time, the oil is decomposed and the soil returns to near normal condition (Foth, 1990); this has a way of flourishing microbial life because of the increased organic matter and nitrogen content of the soil.

Prior to 1978, the oxygen depleting raw POME was freely discharged into public water ways and it adversely affected aquatic life and water quality (Bek-Nielsen *et al.,* 1999). Many researchers are of the view that ground water contamination may result subsequent to contamination of the soil. The Malaysian Environmental Quality Regulations 1997 (Amendment of 1982), (Department of Environment Malaysian, 1999) was Promulgated to mitigate this problem, which requires mills to treat their effluent to a BOD of

100mg/litre or lower before water course discharged and below 5,000mg/litre for land application.

2.9. PALM OIL MILL SLUDGE (POMS)

2.9.1. CHARACTERISTICS

As it has been described earlier, palm oil mill effluent (POME) consists of suspended solids and dissolves solids which are left after POME treatment, commonly named as palm oil mill sludge (POMS). Therefore due to large quantity of POME production each year, the amount of POMS increases respectively. Palm oil mill sludge (POMS) has a higher nutrient value than the

slurry (Zakaria *et al.*, 1994). It has high amount of moisture content, with the pH of 8.4 and enriched with nutrients. It has been shown in Table 2.3 below,

Table 2.2: Physicochemical Analysis of Raw Poms and Empty Fruit Bunch

Parameters	POMS (Average)	Empty fruit bunch
Moisture Content%	85	60
pH	8.4	6.7 ± 0.2
Organic Matter	60	-
Total Organic Carbon	33.0	-
Total Nitrogen	3.6	58.9(%)
Phosphorus (as P_2O_5)	0.9	0.6± 0.1 (%)
Potassium (as K_2O)	2.1	2.4 ± 0.4 (%)

Sources: Yaser *et al., (*2007), Edwards and Bohlen, (1996). All values are in mgL-1 except pH.

(TABLE 2.2) above POMS contains 3.6, 0.9, 2.1 mg/dm^3 of total nitrogen, phosphorus and potassium respectively. This sludge results in bad odours and is considered as a source of surface and ground pollution. Therefore, industries are looking for cost effective sustainable technologies for disposal of industrial sludge.

2.9.2. MANAGEMENT

The oil palm mills generate many by-products and wastes besides the liquid wastes that may have a significant impact on environment if they are not properly dealt with. Among these by-products palm oil mill sludges (POMS) as result of POME treatment plays crucial impact on the environment, which makes it necessary to find a proper technology for mitigating these wastes. According to Chooi, C.F., (1984) palm oil mill sludge (POMS) can be dried and used as a fertilizer as it contains high nutrient value.

Drying is mostly done in open ponds, but during the rainy seasons this process becomes difficult due to slow rate of drying and over flow problem. Composting as well as vermicomposting technology can be used in POMS Management.

2.9.2.1. COMPOSTING TECHNOLOGY

Composting, a microbial technology, is frequently used in stabilization of organic waste either from industrial origin or domestic waste. During the composting process, aerobic microorganisms decompose the substrate, therefore, most of the biodegradable organic compounds are broken down and a portion of remaining organic material is converted in humic acid like substances, with the production of chemically stabilized composted material (Ipek *et al* .,2002). Due to rapid activation of microbes around the root systems the oxygen concentration decreases as a result of partially decomposed or unstable compost. In addition, chemically unstable compost is phyto-toxic due to production of ammonia, ethylene oxide and organic acids (Tam and Tiquia 1994).

Therefore, estimation of compost stability prior to its use is essential for recycling of organic waste in agriculture soils (Khan *et al.,* 2009). The organic residues recycling in soil can mitigate environmental hazards resulting from intensive agriculture [Ordonez et al 2006]. Composting is being advised since it can reduce the volume/weight of sludge (Abd-rahman.*,* 2003). According to Cayuela *et al*. (2005), among the different technologies for olive mill waste recycling, composting is one of the most promising options to transform this material into a valuable organic amendment. Several modification have been made for improving the composting process, increasing the degradation rate and quality of the final compost, such as the addition of biodegradable wastes to reach the optimum C/N ratio of about 30 (Costa *et al.,* 1992), this is commonly known as co-composting. Baharuddin *et al*. (2009) carried out co-composting process using partially treated POME with empty fruit bunches (EFB). The partially treated POME from anaerobic pond was sprayed onto the shredded EFB throughout the treatment. The compost obtained was reported to have considerable amount of calcium, magnesium, phosphorus, potassium and other micro nutrients, therefore it might be suitable to be used as fertilizer for plantation purpose (Baharaddin et al., 2009). Saw mills and furniture industries usually burns the saw dusts generated at the mills which results in air pollution problems. Mixing saw dusts with POMS can mitigate the air pollution and improve the efficiency of composting process (Bhamidimarri et *al.,* 1996). Yaser *et al* carried out the composting process by using the palm oil mill sludge (POMS) with sawdust. The sludges were collected from anaerobic digestion pond and recycled compost came from kitchen waste was added to facilitate the composting process; also the saw dust was collected from the furniture factories. Nutrient content in POMS compost is comparable with other industrial sludge compost. Yaser *et al. (2007)* reported that final compost showed some fertilizer value, but needed to be adjusted to obtain an ideal substrate. As a result, compost of palm oil mill saw dust mixed with sand was found to improve the growth of Cymbopogun citratus (Yaser et a*l.,* 2007). Therefore, composting can be a suitable method for converting palm oil mill sludge into compost that can be used as a fertilizer for plantation purposes.

2.9.2.2. VERMICOMPOSTING TECHNIQUE

Vermicomposting is described as composting or natural conversion of biodegradable waste into high quality fertilizer with the help of earthworms. Vermicomposting is the process in which earthworms are used to convert organic materials into humus-like material known as vermicompost or earthworm compost. Through vermicomposting process physical, chemical and biological reactions take place, resulting changes in the organic matter. The resultant product (vermicast) is much more fragmented, porous and microbial active (Edwards and Bohlen, 1996). In contrast to traditional microbial waste treatment, vermicomposting process results in bioconversion of the organic wastes into two useful products: the earthworm biomass and the vermicompost. Earthworm biomass can further be processed into proteins as a source of animal feeds (Hartenstein and Hartenstein, 1981).

The latter product (vermicompost/casting) is considered as homogenous, has reduced levels of contaminants and tends to hold more nutrients. During the vermicomposting process, important plant nutrients such as nitrogen, phosphorus, potassium, etc. present in the waste are converted into much soluble and available to plants (Ndegwa and Thompson, 2001).

Nagavallemma, K.P., (2004) has reported that the nutrient composition of vermicompost may increase the plant nutrients as compared to the simple composting. Although various physical, chemical and microbial methods of disposal of organic solid waste are currently in use, these methods have some disadvantages and involve high cost. In this regard ‘Vermicomposting’ has been reported to be a viable, cost effective technique for the efficient management of the organic soil waste (Longsdon, G., 1994).

Several researches have demonstrated the ability of earthworms to obtain the biodegradable part of the municipal solid waste as well as industrial wastes (Sabrina *et al*, .2009).

Lumbricus terrestris Butt, K.R., (1993) reported solid paper mill sludge as a suitable feed for under laboratory conditions. The sludge of paper mill did not show adverse effect on the earthworms, although worm growth rate was poor. Elvira *et al* carried out the study on the efficiency of Eisenia anderi in bio converting paper-pulp mill sludge mixed with primary sewage sludge. Elvira *et al* reported that, the mixture of 3:1 ratio found to be suitable medium for optimum growth and reproduction of earthworms. The Epigeic earthworm species live in organic wastes and requires high moisture content, adequate organic material content and dark conditions for proper growth and development (Gunadi and Edwards, 2003). Hartenstein and Hartenstein 1981 carried out the laboratory work study on vermicomposting of activated sludge and reported that approximately 1.0g worm could ingest 4.0g of activated sludge in 5 days. In order to make use of earthworms successful in vermicomposting, its survival, growth and fecundity in different wastes should be known (Garg et al., 2006). As oil palm is a highly nutrient demanding crop, using waste from palm oil mill as fertilizer supplement in place of inorganic nutrients is an environmentally friendly option. Sabrina *et al*. (2009) carried out a study on the vermicomposting of oil palm empty fruit bunches (EFB) and its potential in supplying of nutrients for crop growth. Sabrina *et al.,* (2009) placed 100g of air dried (< 2mm) ground organic residue, empty fruit bunches (EFB) and oil palm frond into the plastic box (20 cm× 7.5 cm× 15 cm) and cover it with pierced lids for aeration. About 4.5g of dried cow dung was added to each box as a food supplement for the earthworms and accelerating the decomposition process. The weight, cocoon production and mortality of earthworms were monitored monthly. The ratios of stocking density treatment were 1:15, 1:10, 1:7.5, 1:6 and 1:5 of earthworm / media. The effect of stocking density at the ratio of 1:10 and 1:15 (earthworm /media) at the fifth week showed the higher growth response of earthworms.

Meanwhile the highest earthworm density showed a higher concentration of total nitrogen (TN), K and Ca in vermicompost as its final product. Therefore it could be concluded that the vermicomposting process improved the quality of the compost materials with respect to nutrient content (Sabrina *et al*., 2009).

CHAPTER THREE

3.0 METHODOLOGY

3.1 DESCRIPTION OF THE STUDY AREA

3.1.1 UMUORGU MILL ADAPALM NIGERIA LIMITED

Umuorgu mill is a subsidiary of Adapalm Nigeria Ltd Ohaji, a centrifugal active palm oil mill industry owned by Imo State Government. It is located at Amuzu Aboh Mbaise L.G.A and lies within latitudes 4°45'N and 7°15'N, and longitudes

6°50'E and 7°25'E with an area of around 5,288 sq km. It is bordered by Abia State on the East and North East, by the Rivers State to the South and West, by Anambra State to the West and North West and Rivers State to the south. Besides Owerri the capital city, Imo State's other major towns are Isu, Okigwe, Oguta, Orlu, Mbaise, Mbano, Mbieri, Orodo and Orsu.

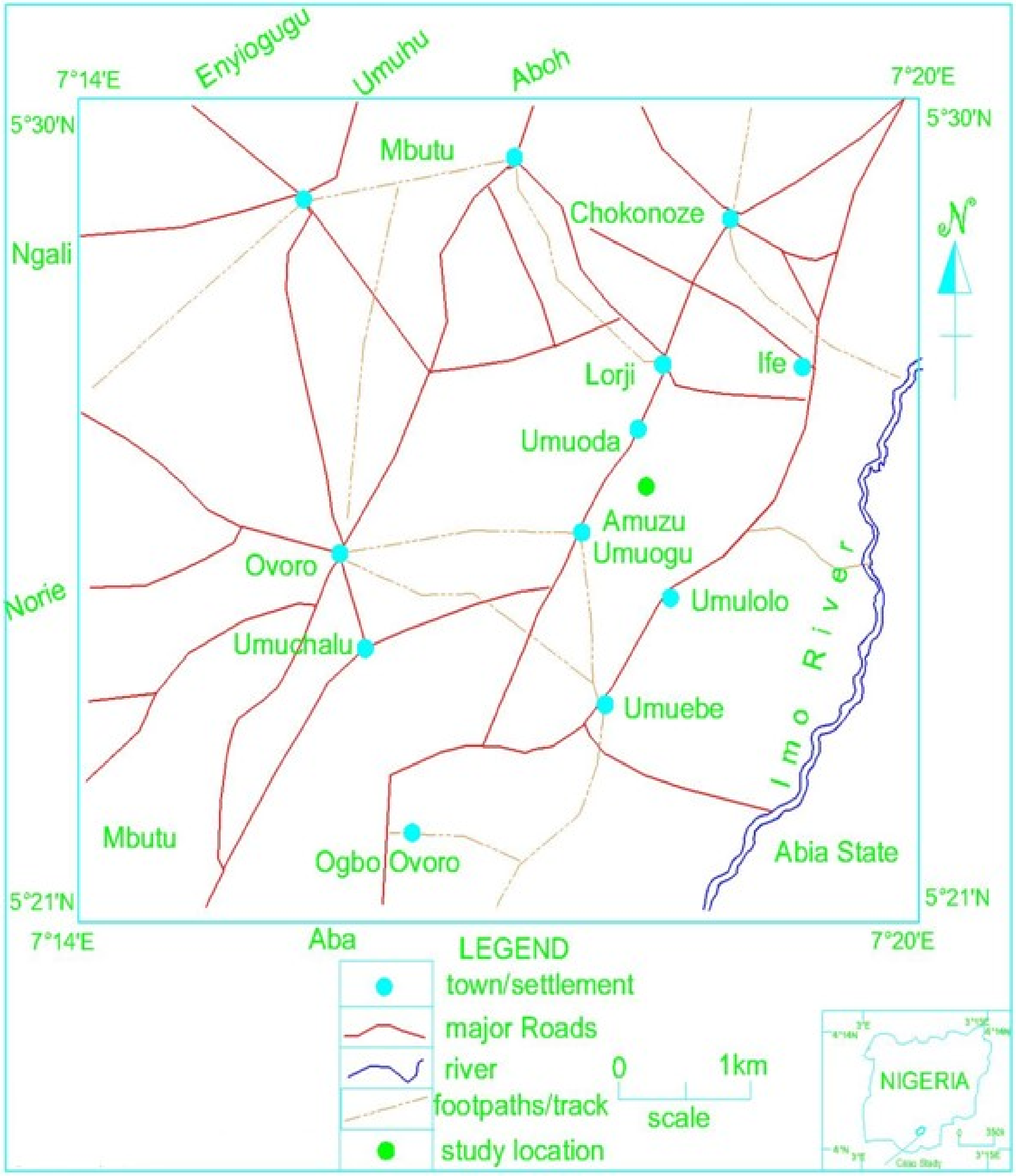

FIGURE 3.1 LOCATION MAP OF THE STUDY AREA

3.1.2. GEOLOGY

Geology of the study area is typical of eastern Nigeria. Imo State is underlain by the Benin Formation of coastal plain sands. This formation, which is of late tertiary age, is rather deep, porous, infertile and highly leached. In some areas like Okigwe, impermeable layers of clay occur near the surface, while in other areas, the soil consists of lateritic material under a superficial layer of fine grained sand.

3.1.3. CLIMATE

Generally, the climate of Imo State is typically humid (Ijioma and Arunsi, 1990). The rainy season begins in April and lasts until October with annual rainfall varying from 1,500mm to 2,200mm (60 to 80 inches). An average annual temperature above 20 °C (68.0 °F) creates an annual relative humidity of 75%, with humidity reaching 90% in the rainy season. The dry season experiences two months of harmattan from late December to late February. The hottest months are between January and March.

3.1.4. VEGETATION

The location of the study area within the tropical rainforest gives it the ecological basis for production of a wide range of tropical agricultural crops with extensive potentialities for industrial usage. Economically exploitable flora like the iroko, mahogany, obeche, bamboo, rubber tree and oil palm tree predominate. However with a high population density and over farming the soil has been degraded and much of the native vegetation has disappeared.

3.1.5. ECONOMIC ACTIVITIES

The location of Imo State within the tropical rainforest gives it the ecological basis for production of a wide range of tropical agricultural crops with extensive potentialities for industrial usage. The economic activity depends primarily on agriculture and commerce and the chief occupation of the people is farming. Their cash crops include oil palm, raffia palm, groundnut, melon, cotton, cocoa, rubber, maize, et cetera. Food crops such as yam, cassava, cocoyam and maize are also produced in large quantities. Imo State also is conducive to livestock production, especially rearing of goats and sheep. Modern poultry farming has been introduced in the state and is practised by a large number of people.

3.2 FIELD PROCEDURES

3.2.1 PRE-FIELD WORK

Reconnaissance field trip was undertaken and routine materials and methods to be used in the field study were noted. The study area was toured round to detect differences in vegetation growth, inter alia, between palm oil mill sites (polluted areas) and other areas (non-polluted) such as non palm oil mill effluent discharged site and a fallow land.

TABLE 3.1: Visual Characteristics of the Polluted and Non-Polluted Site

Characteristics	Site A(Polluted site)	Site B(Non-Polluted site)
Vegetation	Bare without vegetation	Grown with weeds
Colour	Dark Brown	Brown
Moisture	Damp	Dry
Odour	Odorous	Free of odour
Constitution	Debris from processing mill	Debris from leaves.

Site (A)-Polluted site (POME discharge site) and Site (B) - Non- POME Site.

Table 3.1 above shows the different visual characteristics of the soil samples from the sites. The POME site (A) was observed to be bare without vegetation while the non-POME site (B) was grown with weeds. Due to the oil palm effluent discharge noticeable in site (A), the colour of the soil was dark brown, damp and odorous while that of non- POME site (B) was observed to be brown, dry and free of odour. The POME site (A) was also covered with debris from the processing mill while that of the non-POME site B is filled with debris from leaves as it is for typical natural environment (Appendix 5).

In the target study area, which is the active palm oil mill effluent (POME) discharged dump site. Four composite sampling points were spatially spotted, 1metre, 100m, 200m, and 300m respectively in the direction of natural drainage and a sampling point 1000m away from none POME discharged dump site which is served as a control. Soil samples were collected randomly according to the visualized target points in the landscape. Sampling was done two times from each of the spotted point; the process involved using stainless soil auger to dig the soil at fixed depths 0-15cm and 15cm-30cm. The soil samples were bagged in fresh clean brown polyethylene bags. Prior to laboratory analysis, soil samples were air-dried and sieved using 2mm sieve and digested accordingly.

Also, Palm Oil Mill Effluent (POME) samples were collected at the POME discharged pit at two sampling points, before and after (fresh & unfresh) discharged respectively with 500cm^3 plastic bottles and was refrigerated at 3°C.

Samples for BOD were collected in $250cm^3$ brown (BOD) bottles. Prior to analysis, POME samples were filtered through 5mm sieve to remove heavy suspended particles.

3.3 LABORATORY ANALYSIS OF SOIL SAMPLES

3.3.1 PARTICLE SIZE DISTRIBUTION

The particle size analysis was conducted by Bouyoucos hydrometer method as described by Gee and Bauder (1986). Particles determined were total sand, silt and clay expressed in percentages and soil textural classes were estimated using the textural triangle.

About 50g of dried soil by weight was dispensed in $100cm^3$ of Na0H (Sodium Hydroxide). The preparation was placed on a reciprocal shaker for 4 hrs. The sample was poured into $1000cm^3$ measuring cylinder and was made up to a $100cm^3$ marks with de-ionized water. It was plunged by the plunger severally after which the hydrometer was used to take the readings at 40 seconds. The second reading was taking after the soil solution was left for three hours (3 hrs). The temperature readings were recorded at the beginning (40 seconds) T1 and at the end of three hours (T2). A blank sample containing a $100cm^3$ of Na0H was made up to a $100cm^3$ marks with de-ionized water as other samples. Sand, clay and silt properties were obtained using the following equations:

Sand = 100.0 – 2[(H1-B) + 0.2 (Tl-200C)]

Clay = 2(H2-B) + 0.2 (T2-200C)

Silt= 100.0-(% Sand+ Clay)

Where: H1 and T1 are Hydrometer and Thermometer reading respectively at 40 seconds, H2 and T2 are Hydrometer and Thermometer reading at the end of 3hrs.

3.3.2 MOISTURE CONTENT

Moisture content was obtained gravimetrically. A sample of moist soil was weighed and then dried in an oven at a temperature of 105^0C for about 24 hours and finally weighed again. The weight loss represents the soil water.

3.3.3 SOIL pH DETERMINATION

Soil pH was measured potentiometrically in both water and 0.1N KCl as described by Brady and Weil (1999). In this method, a sensing glass electrode is inserted into a soil-liquid mixture that simulates the soil solution (that is, 1:2.5 soil-liquid ratios).

3.3.4 ORGANIC CARBON/ORGANIC MATTER

Soil organic carbon was analyzed by Walkley and Black wet digestion method (Nelson and Sommers, 1982).

Thereafter, organic matter was derived by multiplying the value of organic carbon by a factor of 1.724 (Van Bemmelen's factor).

3.3.5 TOTAL NITROGEN

This was determined by regular micro Kjedahl digestion method (Bremner and Mulvaney, 1982), using concentrated H_2S0_4 and Sodium Sulphate-Copper Sulphate catalyst mixture. Ammonia in the digest was placed with 45% Na0H solution and distilled into 2% Boric acid and then determined by titration with 0.05N HCl.

3.3.6 DETERMINATION OF EXCHANGEABLE BASES (Ca, Mg, K, Na)

The exchangeable bases (Ca, Mg, K, and Na) were extracted with neutral normal ammonium acetate buffered at pH 7.0 (Thomas, 1982). Exchangeable calcium and magnesium were determined by ETDA complex metric titration while exchangeable potassium and sodium were determined by flame photometry (Jackson and Black 1965).

3.3.7 AVAILABLE PHOSPHORUS

This was determined by the Bray II method (Olson and Sommers, 1982). 1g of air dried soil sample was weighed into a $15cm^3$ centrifuge tube and $7cm^3$ of the extracting solution was added, after shaking with mechanical shaker for one minute, the suspension was centrifuged at 2000 rpm for 15 minutes. $2cm^3$ of the clear supernatant was pipette into a $20cm^3$ test tube added with $5cm^3$ distilled water and $2cm^3$ ammonium molybate solution which were properly mixed and added with $1cm^3$ of $SnCl_{2.}2H_2O$ dilute solution. After 5 minutes %

transmittance on the electro photometer was measured at 660µm wave length and standard curve within the range of 0-1ppm P. Then the optical density (O.D) of standard solution against the ppmP was plotted and the content of extractable Phosphorous in the soil sample was calculated.

3.3.8 AVAILABLE SULPHATE- S IN SOIL

This was determined by KH_2PO_4 extraction method (Fox et al 1964) and turbidity method for sulphate- S in soil extract, plant digest and water (Tabatabai, M.A. 1974) by weighing 5g of soil sample into a centrifuge tube, added with 25cm^3 of the extracted solution which was shake for 30minutes on a mechanical shaker and the suspension was filtered through a Whatman No. 42 filter paper. After which turbidity method was applied during when 10ml of the sample aliquot was pipette into a 25cm^3 volumetric flask, added with distilled water that brought the volume to approximately 20cm^3 and 1cm^3 of the gelatin-$BaCl_2$ reagent. Content was thoroughly mixed and was allowed to stand for 30minutes, and then % T and O.D. at 420 mµ was determined within 30-60minutes on a B & L spectronic – 70 electro colorimeter. The content was shake in the flask and poured into the photo-test tube while a set of standard S solutions containing 0, 25, 50, 75, 100, 125 µgSO_4 – S per 25cm^3 from the working standard solution was prepared (the standard solution was contained with 1ml 0f gelatin $BaCl_2$ reagent and 10ml of the extracted solution).

3.3.9 ELECTRICAL CONDUCTIVITY (EC)

This was determined by using the conductivity bridge. A sensing conductivity electrode was inserted into the soil water ratio of 1:2:5.The readings were gotten from the conductivity bridge meter and was measured in μ^{S}/cm.

3.4 LABORATORY ANALYSIS OF POME SAMPLES

3.4.1 pH APHA 4500 $H6^{+}$:

Measurements were carried out by means of a Win Lab pH meter and calibration was checked and/or verified by measuring standard buffer solutions. Calibration was repeated if reading was more than +/-5% of expected reading.

3.4.2 ELECTRICAL CONDUCTIVITY (EC) AND TOTAL DISSOLVED SOLIDS (TDS)

EC and TDS were determined according to APHA-2540-C i.e. instrumental method using the Win Lab TDS meter (Conductivity/TDS meter model MC 126). TDS is reported in mg/l.

3.4.3 TOTAL SUSPENDED SOLIDS (APHA 2540-D)

This was determined by filtering a well-mixed aliquot (100ml) of the sample through a dried and pre-weighed Millipore filter paper using vacuum filtration apparatus. The filter paper was then dried at 105ºC to constant weight. The difference in weight of the filter paper represents the total suspended solids. This was reported in mg/dm^3 after calculation (APHA, 1992).

3.4.4 DISSOLVED OXYGEN (DO)

The dissolved oxygen was determined in–situ using DO meter (Extech 407510A), using the scheme of Ademoroti (1996).

3.4.5 CHEMICAL OXYGEN DEMAND (APHA 5220 B)

COD was determined using the open reflux method (APHA 1992), where a sample is refluxed and digested in a strongly acidic solution with a known amount of excess of potassium dichromate ($K_2Cr_2O_7$). After digestion, the excess un-reacted potassium dichromate was read with a spectrophotometer at 600-nm and results were reported in mg/l. Results were also verified by titrating with a standard solution of ferrous ammonium sulphate.

3.4.6 BIOCHEMICAL OXYGEN DEMAND (APHA 5210B)

BOD, which depends on oxygen uptake by bacteria, was determined using the dilution method according to APHA 5210B (APHA 1992). The amount of oxygen consumed during a fixed period (usually 5 days) is related to the amount of organic natter present in the original sample. Dissolved oxygen of the samples was first determined using the Win Lab Dissolved Oxygen meter and then incubated for five (5) days at 20°C. DO was again measured after a period of five days and BOD in mg/dm^3 was determined from the following calculation and reported accordingly.

$$BOD = \frac{[DOB - DOA] - [DOSB - DOSA]}{D}$$

Where D = dilution factor usually 0.5

DOB =DO of sample before incubation

DOA =DO of sample after incubation

DOSB =DO of sample blank before incubation

DOSA =DO of sample blank after incubation

3.4.7 OIL AND GREASE (API- PR45)

Oil and Grease was determined according to APHA 5520B using a partition-Gravimetric Method. The sample was extracted twice with 1.10 ratio of xylene to sample using a separator funnel. The combined extract after centrifuging was distilled to dryness and cool in a desiccator until a constant weight is obtained. The concentration of Oil and Grease is calculated as thus:

$$\text{Oil and Grease } (mg/dm^3) = Wr/Vs$$

Where:

Wr = Total weight of residue

Vs = Initial volume of sample

3.4.8 NITRATE

Nitrate was determined with the HACL spectrophotometer using the cadmium reduction method. 25cm^3 of the sample was measured and poured out into the sample cell and the contents of one Hach NitraVer 5(Nitrate reagent powder pillows), which is gentisic acid, was added. A five-minute reaction time was allowed after which the concentration of Nitrogen-Nitrate was read with the Spectrophotometer at a wavelength of 400 nm using de- ionized water as reagent blank. Results obtained were in mg/dm^3 Nitrate-Nitrogen. Nitrate concentration (mg/dm^3) in water sample was obtained by conversation factor of 4.43 as stated below.

Calculation:

$$NO_3\ (mg/dm^3) = NO_3\text{-}N\ (mg/dm^3) \times 4.43$$

3.4.9 SULPHATE

The sulphate content of all the samples was determined by the turbid metric method APHA- 427C. The sulphate ion was precipitated in an acetic acid medium with barium chloride ($BaCl_2$) to form barium sulphate crystals of uniform size. Light absorbance of the barium sulphate suspension was measured by a spectrophotometer at 450nm and the SO_4^{2-} concentration in mg/dm^3 was determined by comparing the observed reading with previously prepared calibration graph.

3.5.0 PHOSPHATE

Phosphate was determined by the stannous chloride method (APHA 1985).

Phosphate in water reacts with ammonium molybdenum blue complex in the presence of stannous chloride. The intensity of colour was measured at 690nm using DR 2000 spectrophotometer.

3.5.1 CALCIUM, POTASSIUM AND MAGNESIUM

The concentrations in mg/dm^3 of calcium, potassium and magnesium in the collected samples were determined (after nitric acid digestion) by means of an Atomic Absorption Spectrophotometer. Specific metal standards in the linear range of the metal were used to calibrate the equipment. The concentrated and digested samples were then aspirated and the actual concentrations were obtained by referring to the graph and necessary calculations.

3.6 STATISTICAL ANALYSIS

Data collected were analyzed using descriptive statistics. Pearson Correlation analysis was carried out to find out how variables relate to each other and coefficient of variation was used to determine how variables varied in the study sites. Charts were also used to represent some relationships pictorially. All statistical analysis was carried out with the aid of SAS (1999) and Ms excel 2007.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 RESULTS

4.1.1 DESCRIPTIVE STATISTICS OF SOIL PROPERTIES FOR THE POLLUTED SITE

Fourteen variables (parameters): Organic Carbon(OC), Total nitrogen(N), Sulphate(SO_4^{2-}), Calcium(Ca), Magnesium(Mg), Potassium(K), Sodium(Na), Phosphorus(P), %Sand,% Silt,% Clay, Phosphate(Ph), Moisture Content(MC) and Electrical Conductivity(EC) were analyzed for impacted soil.

These variables showed moderate to high variation in concentration: OC, N, SO_4^{2-}, Ca and Mg varied from1.56-3.75(2.33 ± 0.64) mg/kg, 0.03-0.06(0.04 ± 0.01) mg/kg, 35.00-68.00(51.88 ± 10.96) mg/kg, 1.00-13.80(5.42 ± 4.30) mg/kg and 0.33-4.34(1.09 ± 1.30) mg/kg respectively.

While K, Na, P, %Sand, %Silt and %Clay varied from 0.03-0.07(0.05 ± 1.34)mg/kg, 0.03-0.05(0.04 ± 0.01)mg/kg, 10.14-16.70(13.84 ± 2.13)mg/kg, 71.52-84.52(80.65 ± 4.26)%, 3.92-16.56(10.73 ± 4.10)%, 4.92-18.92(8.63 ± 5.21)% respectively. Meanwhile pH varied from 5.68-7.20(6.68 ± 0.55), MC varied from 7.34-12.73(9.19 ± 1.88) and EC varied from 19.10-239.90(118.16 ± 69.23) µs/cm (Table 4.1).

Table 4.1: Descriptive Statistics of Soil Properties for the Polluted Site

Variable	Minimum	Maximum	Range	Mean	SD
OC (%)	1.56	3.75	2.19	2.33	0.64
N (%)	0.03	0.06	0.03	0.04	0.01
SO_4^{2-}mg/kg	35.00	68.00	33.0	51.88	10.96
Ca (Cmol/kg)	1.00	13.80	12.8	5.42	4.30
Mg(Cmol/kg)	0.33	4.34	4.01	1.09	1.34
K (Cmol/kg)	0.03	0.07	0.04	0.05	0.01
Na(Cmol/kg)	0.03	0.05	0.02	0.04	0.01
P (ppm)	10.14	16.70	5.93	13.84	2.13
Sand (%)	71.52	84.52	13.0	80.65	4.26
Silt (%)	3.92	16.56	12.64	10.73	4.10
Clay (%)	4.92	18.92	14.0	8.63	5.21
pH	5.68	7.20	1.52	6.68	0.55
MC	7.34	12.73	5.39	9.19	1.88
EC (µS/cm)	19.10	239.90	220.8	118.16	69.23

OC- Organic carbon, N- Nitrogen, SO_4^{2-}- Sulphate, Ca- Calcium, Mg- Magnesium, K- Potassium, Na- Sodium, P- phosphorous, MC- Moisture content, EC- Electrical conductivity, SD- Standard deviation.

4.1.2 DESCRIPTIVE STATISTICS OF SOIL PROPERTIES FOR THE CONTROL SITE

Here also in the control site , fourteen (14) variables (parameters); Organic Carbon(OC), Total nitrogen (N), Sulphate (SO_4^{2-}), Calcium(Ca), Magnesium (Mg), Potassium (K), Sodium (Na), Phosphorus (P), %Sand, % Silt, % Clay, Phosphate (PO_4), Moisture Content (MC) and Electrical Conductivity (EC) were analyzed for the non-impacted soil.

These variables showed lower variation in concentration except in the particle size (sand, silt and clay); this is because particle size is a permanent attribute of a soil.

OC, N, SO_4^{2-}, Ca and Mg thus varied from 1.20-1.92 (1.56 ± 0.51) mg/kg, 0.04-0.04(0.04 ± 0.00) mg/kg, 29.00-36.00(32.50 ± 4.95) mg/kg, 0.80-0.90(0.85 ± 0.07) mg/kg and 0.20-0.33(0.27 ± 0.09) mg/kg.

While K, Na, P, %Sand, %Silt and %Clay varied from 0.03-0.04(0.04 ± 0.01)mg/kg, 0.02-0.03(0.03 ± 0.01)mg/kg, 7.40-9.37(8.39 ± 1.39)mg/kg, 76.52-82.52(79.52 ± 4.24)%, 5.56-7.56(6.56 ± 1.41)%, 9.92-17.92(13.92 ± 5.66)%, meanwhile pH varied from 6.20-6.90(6.55 ± 0.49), MC varied from 5.60-7.43(6.52 ± 1.29) and EC varied from 46.20-53.40(49.80 ± 5.09)µs/cm respectively (Table 4.2).

Table 4.2: Descriptive Statistics of Soil Properties for the Control Site

Variable	Minimum	Maximum	Range	Mean	SD
OC (%)	1.20	1.92	0.72	1.56	0.51
N (%)	0.04	0.04	0.00	0.04	0.00
SO_4^{2-}mg/kg	29.00	36.00	7.00	32.50	4.95
Ca (Cmol/kg)	0.80	0.90	0.10	0.85	0.07
Mg(Cmol/kg)	0.20	0.33	0.13	0.27	0.09
K (Cmol/kg)	0.03	0.04	0.01	0.04	0.01
Na(Cmol/kg)	0.02	0.03	0.01	0.03	0.01
P (ppm)	7.40	9.37	1.97	8.39	1.39
Sand (%)	76.52	82.52	6.00	79.52	4.24
Silt (%)	5.56	7.56	2.00	6.56	1.41
Clay (%)	9.92	17.92	8.00	13.92	5.66
pH	6.20	6.90	0.70	6.55	0.49
MC	5.60	7.43	1.83	6.52	1.29
EC (µS/cm)	46.20	53.40	7.20	49.80	5.09

OC- Organic carbon, N- Nitrogen, SO_4^{2-}- Sulphate, Ca- Calcium, Mg- Magnesium, K- Potassium, Na- Sodium, P- phosphorous, MC- Moisture content, EC- Electrical conductivity, SD- Standard deviation.

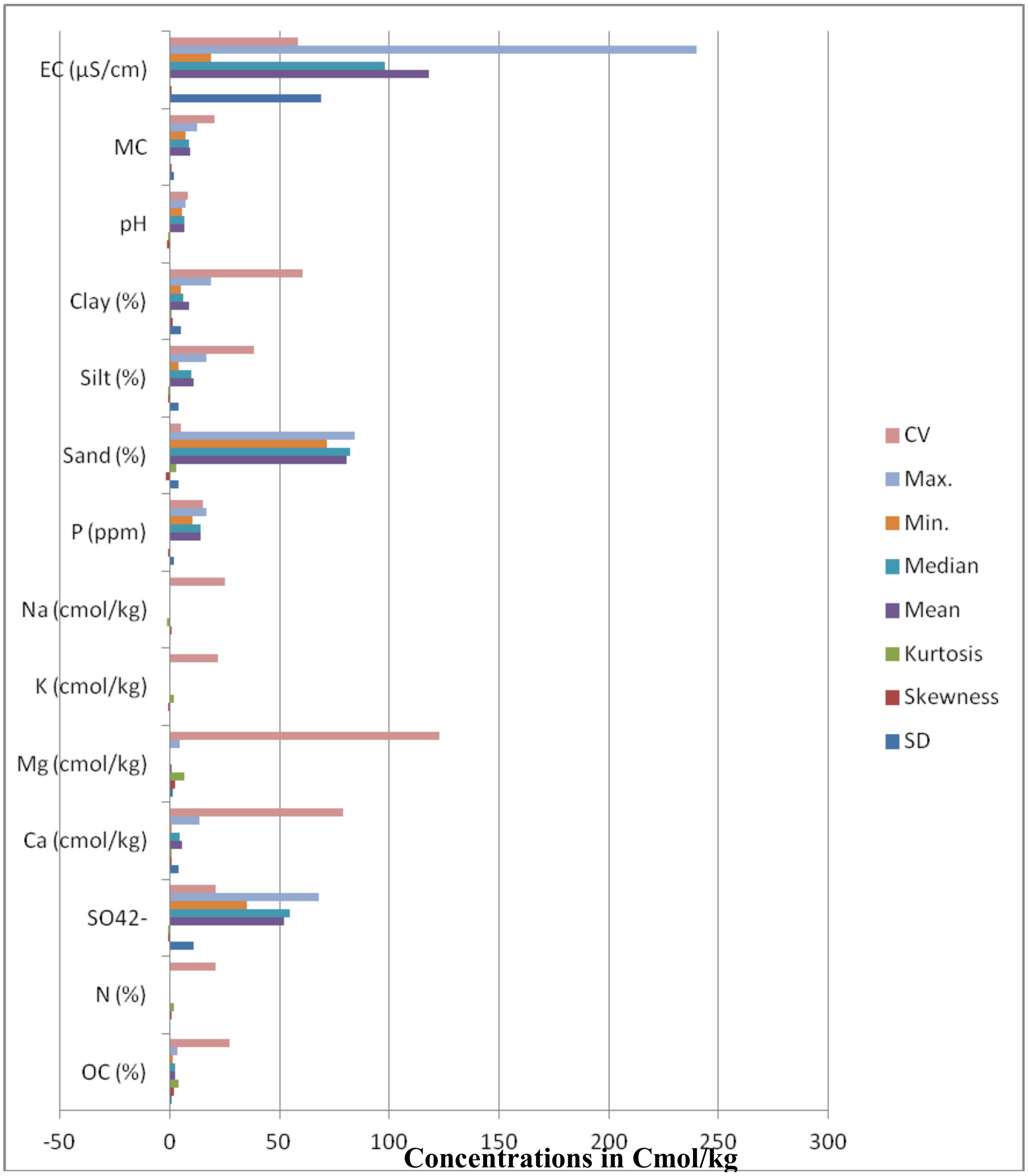

Fig.4.1. Descriptive Statistics of Soil Properties for the Polluted Site.

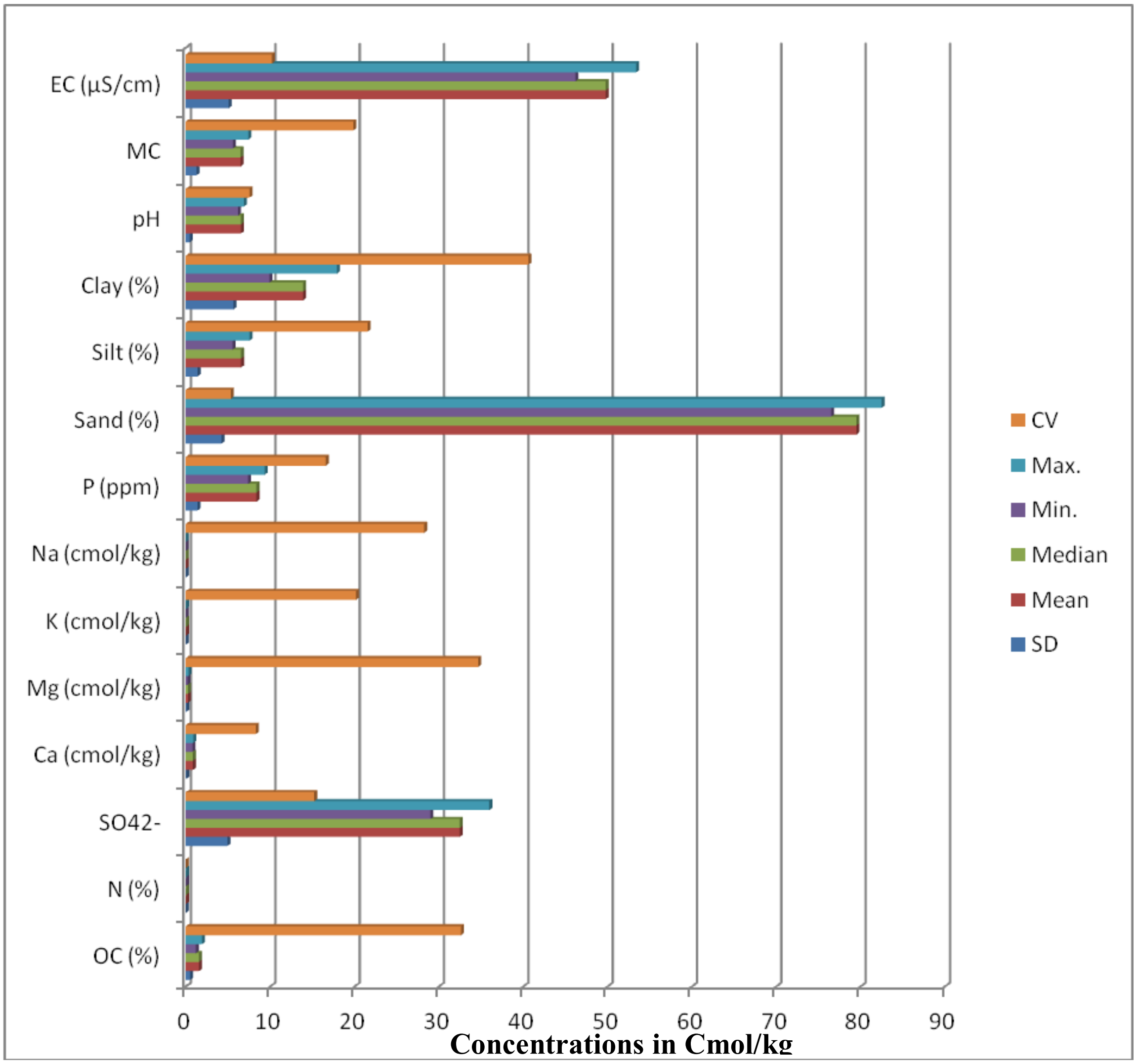

Fig.4.2. Descriptive Statistics of Soil Properties for the Control Site.

4.1.3 CORRELATION OF POLLUTED SITE

Eleven parameters correlated at different levels of significant. Organic carbon correlated significantly with Nitrogen at 5% and Magnesium at 1%, Nitrogen correlated significantly with Magnesium also at 1%, Sulphate correlated significantly with Electrical Conductivity at1% also Calcium correlated significantly with Electrical Conductivity at 1% , Potassium significantly correlated with sodium and phosphorus at 5% and 1% respectively, Sodium significantly correlated with Phosphorus at 1% while Phosphorus significantly correlated with pH at 5%, Sand is significantly correlated with Clay at 5% While pH is the last that significantly correlated with Electrical Conductivity at 1% (Table 4.3).

4.1.4 CORRELATION OF CONTROL SITE

In the Control site also, six parameters correlated at different levels of significance. Potassium is correlated significantly with both Sodium and Sand at 1% respectively. Sodium is correlated significantly with Sand at 1% while Potassium correlated significantly with both Silt and Moisture Content at 5% respectively. Silt also significantly correlated with Moisture Content at 5%.

There was a lower correlation level among the parameters in the control site. Palm oil mill effluents might have affected the polluted site increasing the number of parameters that significantly correlated with each other than that of the control site (Table 4.4).

Table 4.3: Pearson Correlation for the Polluted Site

	OC	N	SO_4^{2-}	Ca	Mg	K	Na	P	Sand	Silt	Clay	pH	MC
OC (%)													
N (%)	0.74*												
SO_4^{2-}mg/kg	0.25	0.62											
Ca (cmol/kg)	-0.09	-0.40	-0.79										
Mg (cmol/kg)	0.83**	0.88**	0.40	-0.29									
K (cmol/kg)	-0.14	-0.32	-0.29	0.47	-0.06								
Na (cmol/kg)	0.21	-0.22	-0.02	0.22	0.06	0.74*							
P (ppm)	0.004	-0.32	-0.37	0.54	-0.02	0.94**	0.82**						
Sand (%)	0.36	0.14	0.36	-0.06	0.02	-0.06	0.31	-0.11					
Silt (%)	-0.19	-0.33	-0.80	0.51	-0.25	-0.09	-0.46	-0.14	-0.22				
Clay (%)	-0.14	0.14	0.33	-0.35	0.18	0.12	0.11	0.20	-0.64*	-0.60			
pH	0.10	-0.27	-0.62	0.54	0.14	0.59	0.51	0.74*	-0.51	0.15	0.30		
MC (%)	-0.27	0.005	0.03	0.22	-0.23	0.24	-0.21	0.002	0.30	0.27	-0.46	-0.47	
EC (µS/cm)	-0.05	0.28	0.82**	-0.75*	0.003	-0.42	-0.21	-0.60	0.55	-0.44	-0.11	-0.89**	0.28

OC- Organic Carbon, N- Nitrogen, SO_4^{2-}- Sulphate, Ca- Calcium, Mg- Magnesium, K- Potassium, Na- Sodium, P- Phosphorous, MC- Moisture Content, EC- Electrical Conductivity, *Significant at 5%, **Significant at 1%.

Table 4.4: Pearson Correlation of the Control Site

	OC	N	SO_4^{2-}	Ca	Mg	K	Na	P	Sand	Silt	Clay	pH	MC
OC (%)													
N (%)	0.53												
SO_4^{2-}mg/kg	0.99	-0.66											
Ca (cmol/kg)	0.68	-0.98	0.79										
Mg (cmol/kg)	0.83	0.05	0.72	0.14									
K (cmol/kg)	0.30	0.66	0.13	-0.50	0.79								
Na (cmol/kg)	0.29	0.66	0.13	-0.50	0.78	0.90**							
P (ppm)	0.96	-0.26	0.89	0.44	0.95	0.56	0.56						
Sand (%)	0.30	0.65	0.13	-0.50	0.79	0.90**	0.99**	0.56					
Silt (%)	0.94	-0.21	0.87	0.39	0.97	0.61	0.61	0.99*	0.61				
Clay (%)	-0.77	-0.14	-0.65	-0.05	-0.99	-0.84	-0.84	-0.92	-0.84	-0.94			
pH	0.89	-0.09	0.81	0.28	0.99	0.69	0.69	0.99	0.69	0.99	-0.97		
MC (%)	-0.97	0.29	-0.91	-0.47	-0.94	-0.53	-0.53	0.99*	-0.53	-0.99*	-0.53	-0.99	

OC- Organic Carbon, N- Nitrogen, SO_4^{2-}- Sulphate, Ca- Calcium, Mg- Magnesium, K- Potassium, Na- Sodium, P- Phosphorous, MC- Moisture Content, EC- Electrical Conductivity, *Significant at 5%, **Significant at 1%.

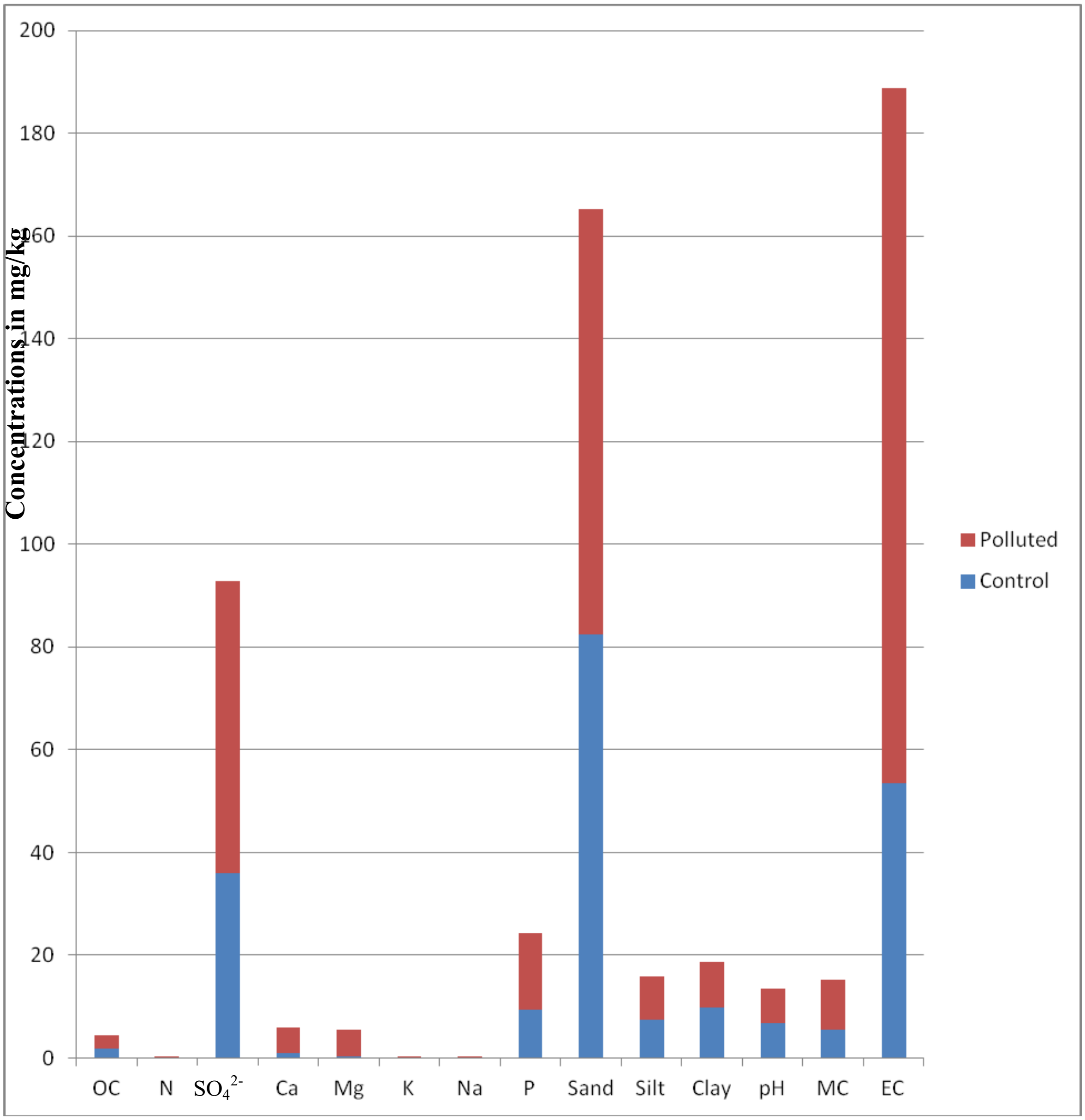

Fig.4.3. Comparison of Soil Physical and Chemical Properties in The first p Layer (0-15 cm depth) of the Polluted and Control Sites.

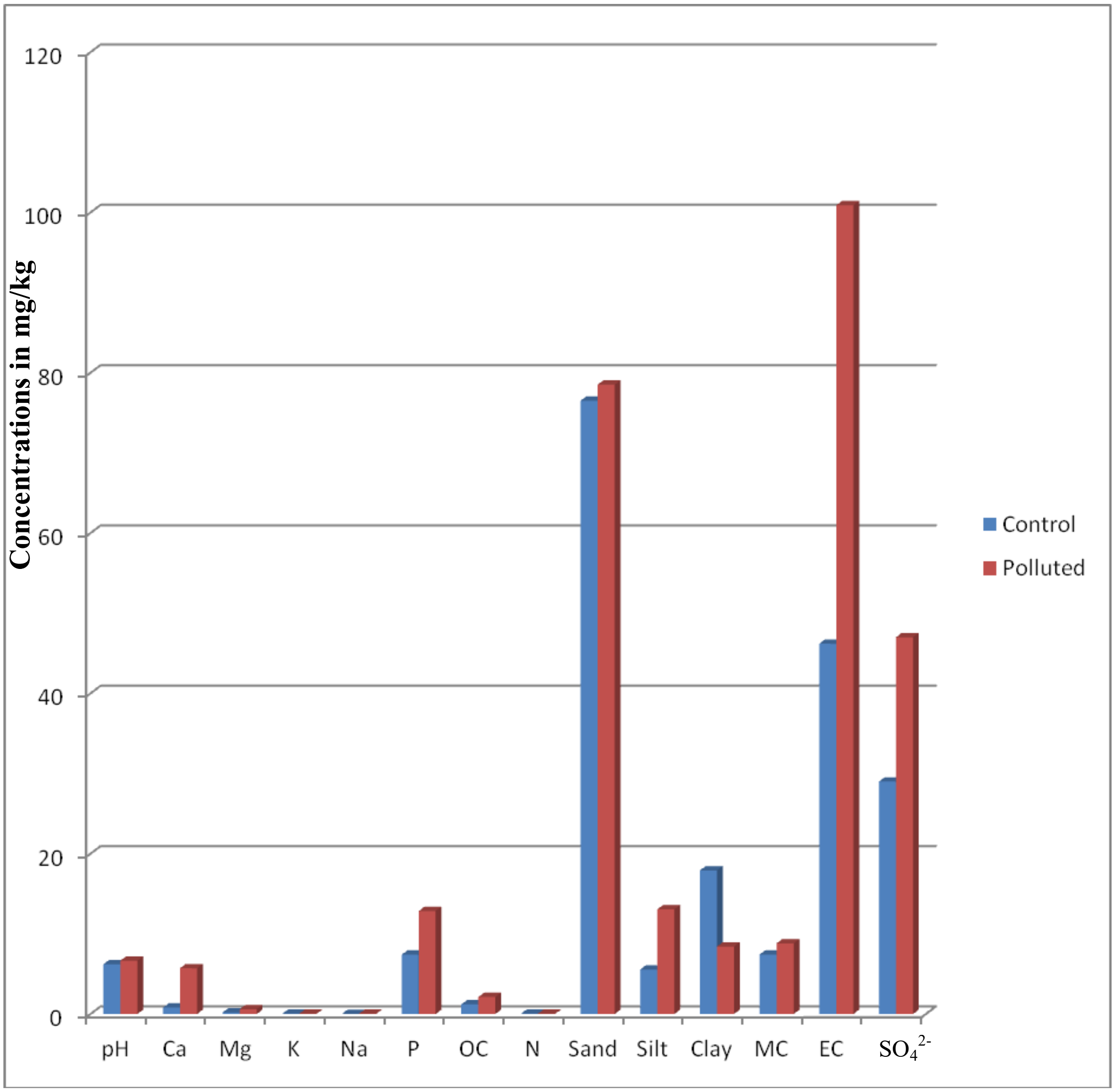

Fig.4.4. Comparison of Soil Physical and Chemical Properties in the second Layer (15-30 cm depth) of the Polluted and Control Sites.

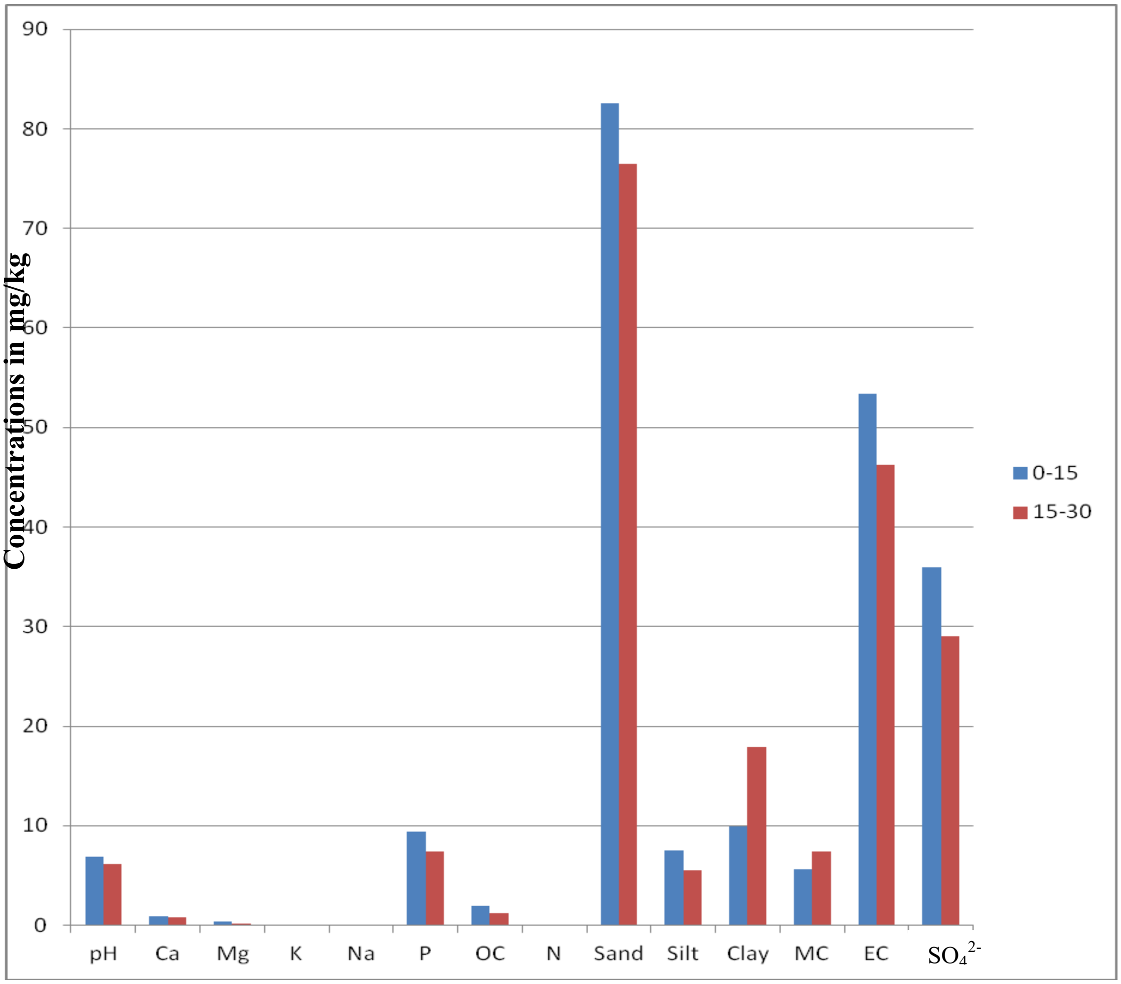

Fig.4.5. Physical and Chemical Properties of Soils within Two Depths (0-15cm and 15-30cm) in the Control Site.

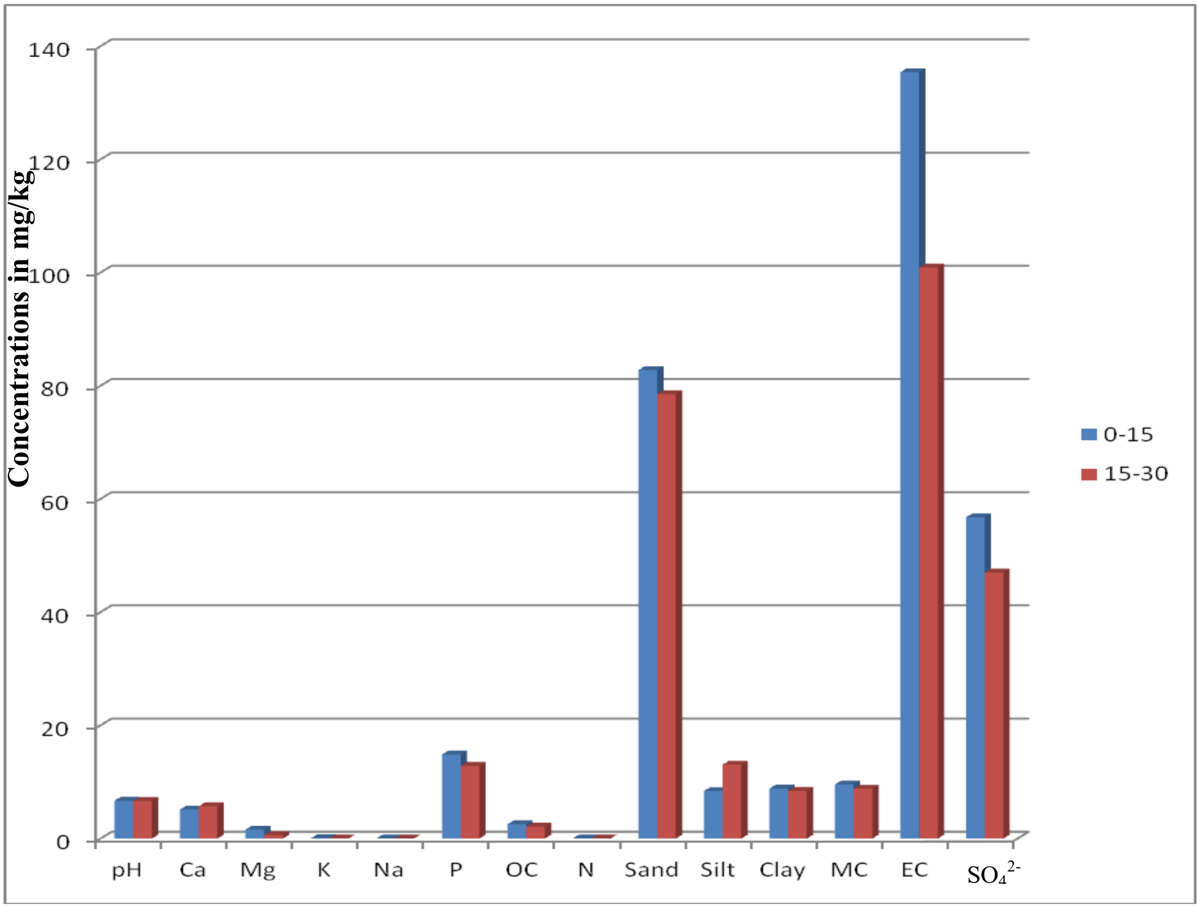

Fig.4.6. Physical and Chemical Properties of Soils within Two Depths (0-15cm and 15-30cm) in the Polluted Site.

4.1.5 Levels of Physicochemical Parameters of POME from the Study Area

The levels of the physicochemical parameters of POME at engine room and effluent pit of the study area are shown in Appendix 2. The levels of pH (Mean = 4.65), Total Acidity (Mean = 7.0mg/dm^3), Phosphate (Mean = 5.66mg/dm^3), Sulphate (Mean = 12.2mg/dm^3), Nitrate (Mean = 34.9mg/dm^3) and Calcium, Magnesium, Potassium has mean levels of (10.9mg/dm^3), (8.0mg/dm^3), (13.64mg/dm^3) respectively with little variations (Table 4.5).

While, Electrical Conductivity, Total Dissolved Solids (TDS), Oil and Grease varied from 224.0 – 268.5(246.3 ± 22.2) µS/cm, 155.57 -129.44 (14.25 ± 13.0) mg/dm^3, 8770 – 9550 (9160 ± 390.0) mg/dm^3, respectively and Total Suspended Solids (TSS), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Dissolved Oxygen (DO) varied from 20515 – 21440 (20977±462.5) mg/dm^3, 10070 - 11050 (10560 ± 490.0) mg/dm^3, 13440 – 14110 (13775 ± 335.0) mg/dm^3,7.11 – 8.01(7.56 ± 0.45) mg/dm^3 respectively with wide variations (Table 4.5).

Table 4.5: Descriptive Statistics of the Physicochemical Parameters of POME

Parameters	Minimum	Maximum	Range	Mean	SE
pH	4.5	4.8	0.3	4.65	0.15
EC, µS/cm	224.0	268.5	44.5	246.3	22.2
TDS, mg/dm^3	129.44	155.57	26.13	142.5	13.0
TSS, mg/dm^3	20515	21440	925	20977	462.5
Total Acidity, mg/dm^3	6.0	8.0	2.0	7.0	0.61
Phosphate, mg/dm^3	5.05	6.27	0.77	5.66	0.60
Sulphate, mg/dm^3	11.55	12.72	1.17	12.2	0.58
Nitrate-Nitrogen, mg/dm^3	32.50	37.25	4.75	34.9	2.37
DO, mg/dm^3	7.11	8.01	0.9	7.56	0.45
BOD, mg/dm^3	10070	11050	980	10560	490.0
COD, mg/dm^3	13440	14110	670	13775	335.0
Oil & Grease, mg/dm^3	8770	9550	955	9160	390.0
Calcium, mg/dm^3	10.71	11.01	0.3	10.9	0.15
Magnesium, mg/dm^3	7.14	8.77	1.63	8.0	0.82
Potassium, mg/dm^3	13.22	14.05	0.83	13.64	0.41

4.1.6 PHYSICOCHEMICAL CHARACTERISTICS OF SOIL AND POME SAMPLES

Table 4.6 below shows the physicochemical characteristics of soil and POME samples. There is increase of the physicochemical parameters of the contaminated soil when compared with the control. The mean pH values recorded for contaminated soil and control were 6.68 ± 0.55 and 6.55 ± 0.55 respectively and 4.65 ± 0.15 for the effluent.

The mean values for Electrical Conductivity, Moisture Content, Phosphate, Nitrate, Sulphate, Calcium, Sodium, Potassium, Magnesium and the particle size Sand, Silt, Clay in the contaminated soil were 118.16± 69.23µs/cm, 9.19 ± 1.88,13.84 ± 2.13mg/kg, 0.04 ± 0.01mg/kg, 51.88 ± 10.96mg/kg, 5.42 ± 4.30mg/kg,0.04 ± 0.01mg/kg, 0.05 ± 0.01mg/kg, 1.09 ± 1.34mg/kg, 80.65 ± 4.26%, 10.73± 4.10% , 8.63 ± 5.21%respectively.

The mean values for Electrical Conductivity, Moisture Content, Phosphate, Nitrate, Sulphate, Calcium, Sodium, Potassium, Magnesium and the particle size Sand, Silt ,Clay for the control soil were 49.80 ± 5.09µs/cm, 6.52 ± 1.29, 8.39 ± 1.39mg/kg, 0.04 ± 0.00mg/kg, 32.50 ± 4.95mg/kg, 0.85 ± 0.07mg/kg, 03.0 ± 0.01mg/kg, 0.04 ± 0.01mg/kg, 0.27 ± 0.09mg/kg, 79.52 ± 4.24%, 6.56 ±1.41%, 13.92 ± 5.66% respectively.

The mean values of the Electrical Conductivity, Oil and Grease, Total Acidity, Dissolved Oxygen, Biochemical Oxygen Demand, Chemical Oxygen Demand, Total Suspended Solids, Total Dissolved Solids, Phosphate, Nitrate ,Sulphate and Calcium, Magnesium, Potassium for the raw effluent were 246.3± 22.2µs/cm, 9160 ± 390.0mg/dm^3, 7.0 ± 0.99mg/dm^3, 7.56 ± 0.45mg/dm^3, 10560 ± 490.0mg/dm^3, 13775 ± 335.0mg/dm^3, 20977± 462.5mg/dm^3, 142.5 ± 13.0mg/dm^3, 5.66 ± 0.61mg/dm^3, 34.9 ± 2.37mg/dm^3, 12.2 ± 0.58mg/dm^3, 10.9 ± 0.15mg/dm^3, 8.0 ± 0.82mg/dm^3, 13.64 ± 0.41mg/dm^3 respectively. The alteration of the contaminated soil when compared with the control is due to the deposition of the raw effluent in the soil. The effluent has higher concentration in the levels of physicochemical variables.

Table 4.6: The Mean Values of the Physicochemical Characteristics of the Polluted Soil, Control Soil and POME Samples

Parameter	Polluted Soil	Control Soil	POME Sample
pH	6.69	6.55	4.65
Conductivity (μS/cm)	118.16	49.80	246.3
Oil and Grease (mg/dm^3)	N.A	N.A	9160
Total Organic Carbon (%)	2.3	1.5	N.A
Phosphate (mg/dm^3)	N.A	N.A	5.66
Phosphorus P (ppm)	13.84	8.39	N.A
Nitrate-Nitrogen (mg/kg)	0.04	0.04	34.9
Sulphate (mg/kg)	51.88	32.50	12.2
Calcium (mg/kg)	5.42	0.85	10.9
Sodium (mg/kg)	0.4	0.03	N.A
Potassium (mg/kg)	0.5	0.04	13.64
Magnesium (mg/kg)	1.09	0.27	8.0
BOD (mg/dm^3)	N.A	N.A	10560
COD (mg/dm^3)	N.A	N.A	13775
DO	N.A	N.A	7.56
TSS (mg/dm^3)	N.A	N.A	20977
TDS (mg/dm^3)	N.A	N.A	142.5
Total Acidity (mg/dm^3)	N.A	N.A	7.0
Sand (%)	80.65	79.52	N.A
Clay (%)	8.63	13.92	N.A
Silt (%)	10.73	6.56	N.A

N.A »» Not Applicable

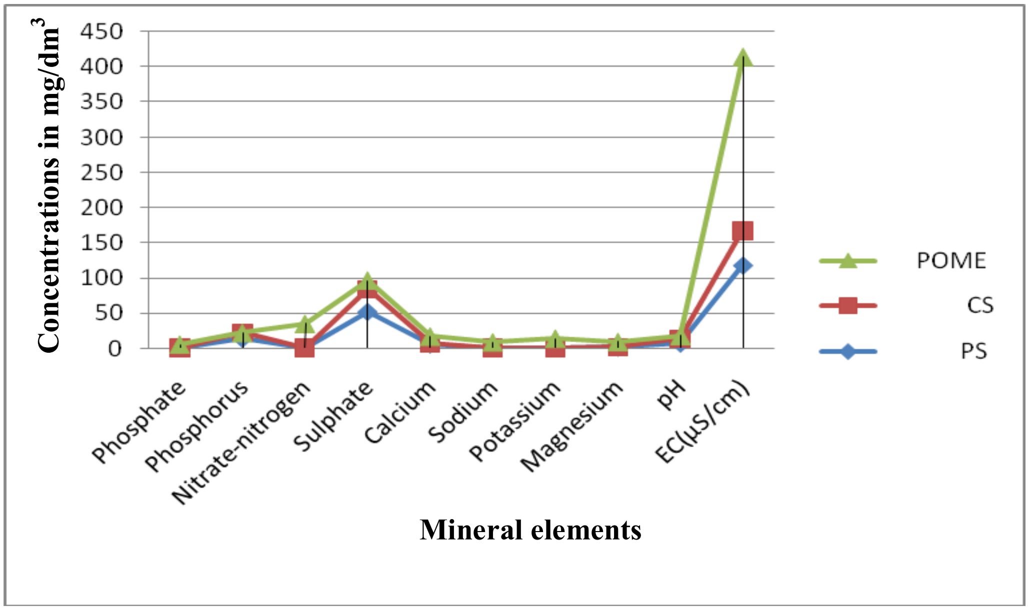

Fig.4.7.Graph Representing Mineral Elements in Polluted Soil(PS), Control Soil(CS) & Palm Oil Mill Effluent(POME)

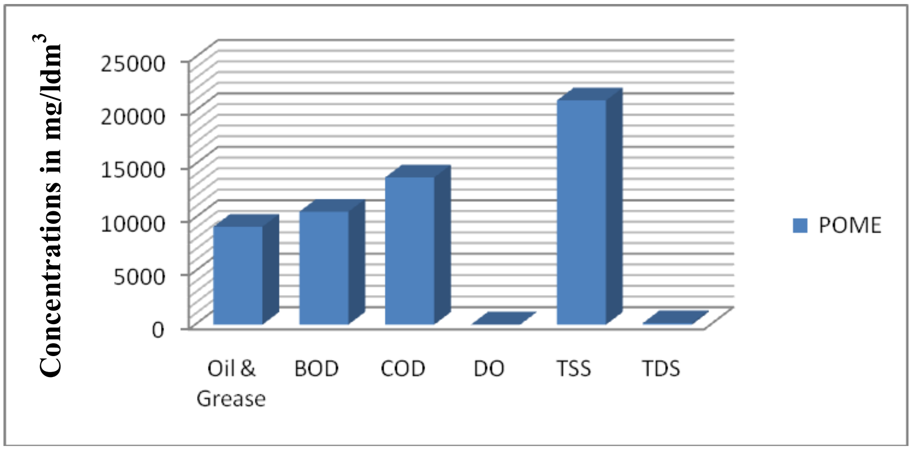

Fig.4.8. Bar Chart of Total Organic Loading in POME

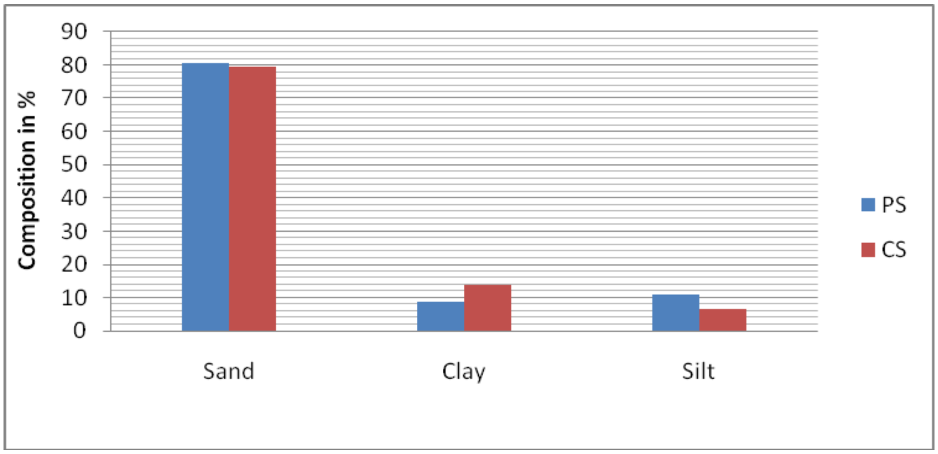

Fig.4.9. Bar Chart Representing Textural Classes in PS & CS

4.2 DISCUSSION

4.2.1 CHARACTERIZATION OF SOILS OF THE STUDY SITES

4.2.2 PHYSICAL PROPERTIES

Appendix 1 includes results of selected physical properties of soils of the two study sites. The soils were predominantly sandy (76.52 to 82.77%) in the two sites; evidence which shows that Palm Oil Mill Effluents (POME) can easily infiltrate the soil pores of the polluted site. The high sand content of the sites could be attributed to the parent material which is of coastal plain sands (Ofomata, 1975). Clay content increased (9.92 to 17.92%) down the depth in the control site while it decreased (8.83 to 8.42%) down the depth in the polluted site. This has similar result with Obi *et al*. (2011) in Okija, which explains pedogenetically, that clay content increases down the depth in soils with minimal pedoturbation. They reported that surface soils of POME polluted soils have more clay contents than the sub-surface. The colloidal suspension of water and total dissolved solutes in the palm oil mill effluent could be contributory for high clay contents since it includes all fine particles inherent in or introduced to the soil system. This could be a further confirmation of the effect of land use on the characteristics of sample distribution especially of the particle size fractions (psf). This variation in clay content undoubtedly will affect the silt/clay ratio which is an indication of extent of weathering and soil development. The gravimetric moisture content of soils of the polluted site was found to be higher than the control site in both depths (Appendix1). The value increased downward in the control site while it decreased downward in the polluted site. This could be as a result of water content of the palm oil mill effluents discharged unto the soil.

The descriptive statistics of soil properties of the polluted site (Table 4.1) shows that the mean and median values of the physical properties were largely similar with the exception of clay content dominated by outliers indicating that the soil properties were not actually from the same source showing that the palm oil mill effluent (POME) may have had significant effect on the distribution. When compared with the mean and median values of the control site (Table 4. 2), it shows that outliers did not dominate the central tendency of the soil physical properties indicating soils whose land use had not much affected the inherent soil physical properties. These are preliminary indicators that apart from the soil properties which were normally distributed, palm oil mill effluent has significantly influenced the characteristics of distribution of the particle size fractions of the polluted site.

The coefficient of variation ranked according to Wilding *et al*. (1994) showed a low variation (CV = 5%) in the sand content of soils of the polluted site while the clay content varied high (CV = 60%). The clay content also varied highly (CV = 40%) in the control site but that of the palm oil mill effluent soils varied 20% higher. This could be due to the effect of the palm oil mill effluents on the distribution of particle size fractions since it contains many colloidal particles and total dissolved solutes. The soil physical properties of the polluted site were neither skewed nor kurtous (Figure 4.1).

4.2.3 CHEMICAL PROPERTIES

Appendix 1 includes results of selected chemical properties of the two study sites. The soil reactions are slightly acidic to neutral (6.20 – 6.90) from surface to the subsurface of the study sites. The pH of the surface soil of the control site (pH = 6.90) was higher than that of the polluted site (pH = 6.69) while in the subsurface, the pH of the polluted site was higher. It has been reported that when raw POME is discharged, the pH is acidic (Hemming, 1977) but seems to gradually change to alkaline as biodegradation progresses. Obi *et al.* (2011) reported that the pH value of an active palm oil mill was found to be slightly higher than a control but adduced it to the effect of parent material and separation processes of the kernel from the shell during the milling operation. The total exchangeable bases (Ca + Mg + K + Na) in the study sites ranged from 1.05 to 6.82 $CMolkg^{-1}$. The total exchangeable bases decreased down the depths in the two study sites with the soils of the polluted site recording higher values in both depths. The higher value of total exchangeable bases recorded in the polluted site could be due to biodegradation of POME that were ongoing in the site. Values of exchangeable Ca^{2+} were comparably higher in the polluted site (5.13 $CMolkg^{-1}$ and 5.71 $CMolkg^{1}$ for the surface and subsurface, respectively) than the control (0.9 $CMolkg^{-1}$ and 0.8 $CMolkg^{-1}$ for the surface and subsurface, respectively). The Mg^{2+}, K^+ and Na^+ concentrations of the polluted site were also higher than that of the control (Appendix 1). The major sources of cations are mineral weathering, mineralization of organic matter and soil amendments, particularly lime and fertilizers (Foth, 1990). Studies have confirmed the use of treated POME for soil amendments. Higher values of available phosphorous were recorded in soils of the polluted site (14.85 and 12.84 ppm for the surface and subsurface, respectively). In both sites, the values decreased down the depth. The availability of organic phosphates in the soil is governed essentially by the amount of organic carbon in the soil and mineralization rate (Foth, 1990), while availability of inorganic phosphorous is controlled mainly by soil pH which also invariably controls the amount of soluble iron, aluminium, manganese and calcium. From the results (Appendix 1), higher organic carbon content in the polluted site implied higher available phosphorous. Total N differed only at the surface soils of the study sites with the polluted soil having a little higher. Soil organic carbon typically contains about 5% nitrogen; therefore the distribution of soil nitrogen closely parallels that of soil organic carbon (Brady and Weil, 1999). Higher organic carbon and increased nitrogen content have been observed in palm oil mill sites (active) in similar studies (Okwute and Isu, 2007; Ngan et al, 1996) but this could be dependent on the age of the mill which may affect organic matter decomposition and thus nitrogen content through mineralization. The results showed that the palm oil mill effluent polluted soils have higher organic carbon contents with the mean as 2.54 and 2.12% for the surface and subsurface layers, respectively with values decreasing with depth in both sites. This could be as a result of litter accumulation on the surface of soil. The results have shown that soils of the study sites are of low organic matter content which could be due to climatic conditions of high humidity and warm temperatures. In tropical soils, mineralization is accelerated, so nutrient release is rapid, but residual organic matter accumulation is lower than in cooler soils (Brady and Weil, 1999). The polluted site had a higher electrical conductivity (135.4 µs/cm) but was not appreciable to classify the soil as saline as the critical limit for salinity is 400 µs/cm (U.S. Salinity Laboratory Staff, 1995).

The descriptive statistics of soil properties of the polluted site presented above (Table 4.1) shows that with the exception of electrical conductivity, the mean and median of the chemical properties were largely similar which indicates that outliers did not dominate the measures of the central tendency. Again, in the control site (Table 4.2), the mean and median of the chemical properties were similar and thus outliers did not dominate the measure of their central tendency. In the polluted site, exchangeable bases viz, Ca^{2+} and Mg^{2+} varied highly ($CV \geq 79\% \leq 123\%$) while Na^{+} and K^{+} varied moderately ($CV \geq 21\% \leq 25\%$). Also, organic carbon, sulphate, nitrogen, phosphorous and moisture content all varied moderately (CV $\geq$ 15% $\leq$ 27%) in the site. Most of the chemical properties of soils of the control site varied moderately.

Likely as will always be expected, the Pearson correlation coefficient (Table 4.3) revealed that there was a significant positive correlation ($r = 0.74$, $p \leq 0.05$) between the organic carbon content and nitrogen content of the palm oil mill effluent polluted soil. Brady and Weil (1999) reported that soil organic carbon typically contains about 5% nitrogen and that the distribution of soil nitrogen closely parallels that of soil organic carbon. It would be expected that as more of the organic carbon from the POME is added to the soil, nitrogen content of the soil will be increasing. More so, the results revealed that the sand content of the polluted site decreased as the clay content increased at a rate of 64% ($r = -0.64$, $p \leq 0.05$). Such non-significant but important relationships also existed in the control site (Table 4. 4).

4.2.4 CHARACTERIZATION OF POME ON THE STUDY SITE

From the result of POME on physicochemical parameters of the study site(Appendix 2) it would be observed that POME contains large amounts of total solids, oil and grease and is characterized by low pH due to organic acid produced in the fermentation process. The influence of POME on soil physicochemical characteristics is discussed on the following sub-headings:

4.2.4.1 PARAMETERS ASSOCIATED WITH POME

POME in this study is characterized with mineral elements and substantial amount of organic loads. It was observed that POME contained appreciable concentrations of mineral elements when compared to control soil (CS) and polluted soil (PS) (Table 4.6).This agrees with the findings of (Habib et al., 1997 and Muhrizal et al., 1997) which states that palm oil mill effluent contains appreciable amounts of N, P, K, Mg, and Ca that are vital nutrient elements for plant growth. pH was also significantly reduced in the palm oil mill effluent (pH 4.65) when compared to polluted soil and control soil (pH 6.69 &6.55) respectively. This could also be attributed to excess organic acids produced during fermentation process. POME was also observed to contain substantial amount of total suspended solids (TSS) (20977mg/dm^3), oil & grease (9160mg/dm^3), BOD (10560) and COD (13775 mg/dm^3). This result is similar to Ma A.N., (2000) in his respective studies (fig.4.7&4.8).

In addition and as earlier described in this chapter, soil composition, clay content increased (9.92 to 17.92%) down the depth in the control soil (CS) but conversely decreased (8.83 to 8.42%) down the polluted site (PS) (Appendix 1). This has similar result with Obi et al (2011) which explains that pedogenetically, clay content increases down the depth in soils with minimal pedoturbation. This possibly explains why surface soil of POME polluted soils has more clay contents than sub surface.

4.2.4.2 EFFECTS ASSOCIATED WITH POME POLLUTED SOIL (PS)

Polluted soil in the study was observed to have higher physicochemical parameters when compared to control soil (CS). The mineral elements of PS were greater than CS in terms of Ca (5.42>0.85), K (0.5>0.04), Sulphate (51.88>32.50), Mg (1.09>0.27), Phosphorus (13.84>8.39). These are indicators showing that POME may have significantly influenced and elevated mineral elements of the soil (Table 4.6). This result laid credence to Hui, Y.H., 1992, Hartley, C.N.S., 1998 and Keu, S.T., 2005 which state that POME increases organic carbon and majority of the nutrients, water holding capacity and porosity of the soil. This can also be substantiated with (Habib et al, 1997 and Muhrizal et al, 1997) which states that POME contains appreciable amount of minerals vital for plant growth. Consequently, pH in PS (6.69) slightly increased when compared to CS (6.55). This trend could have been influenced by the presence of mineral element from the POME introduced to the soil with its concomitant changes to alkaline as a result of biodegradation. This is also in line with Okwute et al (2007), which attributed the increase to addition of POME onto the soil which incidentally increased the levels of exchangeable bases.

In Table 4.3, EC correlated negatively with pH. This shows that any increase in EC will result to decrease in pH. This also is in line with Aziz et al., 2007 which states that POME brings about undesirable changes such as decrease in pH increase in salinity (EC).

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 SUMMARY

Experimental results of this study showed appreciable variations in concentration of Palm oil mill effluents (POME), Polluted soil (PS) and Control soil (CS). These variations are attributed to the huge quantities of bye products from the oil extraction process. Appreciable variations in mineral elements were observed in PS, POME and CS with significant increase recorded in POME. Although, there were slight variations in concentration with PS and CS, it is obvious that POME of Umorgu processing mill contains considerable mineral elements, low pH and appreciable quantities of solids both suspended solids and dissolved solids commonly called palm oil mill sludge (POMS). Its presence in the soil could significantly enrich the soil because of the elevated values of mineral elements observed in the polluted soil. However, POME in this study contributed to the environmental pollution of Umorgu soil due to its perceived clogging and water logging nature coupled with the production of huge quantities of bye products from the oil extraction process.

5.2 CONCLUSION

In conclusion, POME having substantial quantities of palm oil mill sludge (POMS) could pose serious threat to environmental issues if not formally treated before it is discharged to the surrounding environment. Also, POMS if properly harnessed has higher nutrient value enriched with essential minerals needed for plant growth.

5.3 RECOMMENDATION

Considering the substantial organic load and mineral elements contained in POME, attention should be geared towards developing a sustainable technology that is aimed at recovering these organic based products (carbohydrates, proteins and fatty acids) that could serve as raw materials for industrial production in areas like soap making, fermentation substrate in the production of various metabolites and other forms of biotechnological ingenuity.

REFERENCES

Abd-rahman, R., Kalil Mohd, S., and Abu Zahrim, Y. (2003). Composting palm oil mill sludge-sawdust: effect of different amount of sawdust. In:Proceedings of national workshop in conjunction with ARRPET workshop on wastewater treatment and recycling 2: removal chloroorganics and heavy metals. *ISBN 983-2982-04-9.*

Acea, M.J., Carballas, T. (1996). Microbial response to organic amendments in a forest soil. *Bioresource Technol. 57: 193-199.*

Ademorati, M. A. (1996). Standard Methods for water and effluent analysis. *Foludex Press Ltd, Ibadan. 1st ed*.Pp 80-83.

Agamuthu, P. (1995). Palm oil mill effluent treatment and utilization. In: Sastry CA, Hashim MA, Agamuthu P (eds) Waste treatment plant. *Narosa Publishing House, New Delhi*, pp: 338-360.

Agungjaya, A. (2007).Crude Palm Oil as a Raw Material and Processing Methods. *Manufacturers conference journals* , Indonesia.

Ahmad, A.L., Ismail, S., and Bhatia, S. (2005).Ultra filtration behavior in the treatment of agro industry effluent: Pilot scale studies. *Chemical Engineering Sci.*, 60: 5385-5394.

Ahmad, A., Ismail, S., and Bhatia, S. (2003). Water Recycling from Palm Oil Mill Effluent (POME) using Membrane Technology. *Desalination*, 57:87- 95.

Ahmad, A.L., Bhatia.S., Ibrahim.N., and Tan, J.M.(2000).Membrane technology in palm oil mill effluent treatment. *Chemical and process engineering conference 2000, Singapore*.

APHA, AWWA and WEF, (1992). Standard Methods for the Examination of Water and Wastewater, *20th Edition, Washington D.C., USA*.

Aziz Hanida and Abudul, B.T. (2007). Reactive extraction of sugar from oil palm empty fruit bunch hydrolysate using naphthalene-2-boronic acid, *University Saints Malaysia, Thesis(Masters of Sciences).*

Baharaddin, A.S., Wakisaka, M., Shirai, Y., Abd- AZIZ,S., Rahman, A.A., and Hassan,M.A.(2009). Composting of empty fruit bunches and partially treated palm oil mill effluents in pilot scale. *International J. Agriculture Res., 4: 69-78.*

Bek-Nielsen, C., Singh. G.,and Toh, T.S .(1999). Bioremediation of Palm Oil Mill Effluent. In: Proceedings Porim International Palm Oil Congress 16thFebruary 1999, *Kuala Lumpur, Malaysia.*

Bhamidimarri,S.M.R. and Pandey,S.P. (1996).Aerobic thermophilic composting of piggery solid wastes. *Water Science and Technol.,* 33: 89-94.

Black, C.A. (1965). Method of Soil Analysis Vol. II. 573-590, *American Society of Agronomy, Madison, USA.*

Brady, C., and Weil, R. (1999). The Nature and Properties of Soils. *USA: Prentice Hall Inc.*

Bremner, J.M., and Mulvaney, C.S. (1982). Methods of soil analysis, part 2 chemical and microbiological properties, 595-624.

Buol, S.W., Southard, R.J., Graham, R.C., and McDaniel, P.A. (2003). Soil Genesis and Classification, 5th Edition, *lowa State press- Blackwell, Ames, IA.*

Catharina, Y.W., Keshun Liu and Yao-wen Huang (1999). (*eds.).* Asian Foods.

Cayuela, M.L., Sanchez-Monedero, M.A., and Roig,A.(2005). Evaluation of two different aeration systems for composting two-phase olive mill wastes. *Process Biochemistry*, 41: 616-623.

Chan, K. W., Watson, I. & Lim, K. C. (1980). Use of Oil Palm Waste Material for Increased Production. *Paper Presented at the Conference on Soil Science and Agricultural development in Malaysia, Kuala Lumpur, Malaysia.*

Chooi, C.F. (1984). Ponding system for palm oil mill effluent treatment.

Costa, F., García, C., and Hernández, T.(1992). Residuos orgánicos urbanos. Manejoy utilizació n. CSIC, Madrid.

Davis, J.B. (1978). Palm oil mill effluent: a review of methods proposed for its treatment. *Tropical Sci. 20: 233.*

Dolmat, M. T., Lim, K. H., Zakaria, Z. Z.,and Hassan, A. H. (1987). Recent Studies on the Effects of Land Application of Palm Oil Mill Effluent on Oil Palm and the Environment. In: Proceedings of International Oil Palm, Palm Oil Conferences (eds) B. Hj. Abdul Halim; Hassan C; B.J. Woond, and. E. PushParajah (eds.) 2:596 – 604.

Donahue, Roy Luther, Miller, Raymond, W., and Shickluna, John C. (1977). *Soils: An Introduction to Soils and Plant Growth*. *Prentice-Hall. ISBN* 0-13-821918-4.

Edwards, C.A. and Bohlen,P.J.(1996). Biology and ecology of earthworms, Spinger. *Environmental Quality Act 1974, (2005).*

Edwards, R.J. (1998). "Typical Soil Characteristics of Various Terrains*".* *Retrieved 2 July 2008.*

Elvira, C., Goicoechea, M., Sampdro, L., Mato, S., and Nogales, R. (1996). Bioconversion of solid paper-pulp mill sludge by earthworms. *Bioresource Technol.,* 75: 173-177.

Eswaran, H., lal ,R., and Reich, P.F.(2002). Land degradation. An overview conference on land degradation and desertification. khon kaen, *Thailand: Oxford Press,* New Dehli, India.

Ezemonye, L.I.N., Ogeleka,D.F., and Okieimen,F.E.(2008) Lethal toxicity of industrial chemicals to early life stages of Tilapia guineensis. *Journal of Hazardous Materials, 157(1): 64-68.*

Faessler, Kolmetz (2004). Advanced Fractionation of the Oleo Chemical Industry*, Oil and Fat Conference.*

Foth, H.D .(1990). Fundamentals of Soil Science. *Canada: John Wiley and Sons. Inc.*

Fox, R. L., Olson, R.A., and Rhoades, H.F. (1964). Evaluating the sulfur status of soils by plants and soil tests. *Soil Sci. Soc. Am. Proc*. 28: 243-246.

Garg, P., Gupta, A., and Satya, S. (2006). Vermicomposting of different types of waste using *Eisenia foetida*: A comparative study. *Bioresource Technol*., 97(3): 391-395.

Gee, G.W., and Bauder, J.W. (1986). Particle- size analysis. P. 383-411.

Gerhard Robbelen, Downey Keith, R., and Amram Ashri (1989). Oil Crops of the World. *New York: McGraw-Hill, Inc.*

Gunadi, B., and Edwards, C.A. (2003). The effects of multiple applications of different organic wastes on the growth, fecundity and survival of *Eisenia fetida* (Savigny)(Lumbricidae). *Pedobiologia- International J. Soil and Biol.,* 47: 321-329.

Gunn, J.S., Sly, J.M.A., and Shapas, L.C. (1961). The development of improved nursery practices for the oil palm in West Africa, *J.W. Afr. Inst. Oil Palm Res. 3:198.*

Habib, M.A.B., Yusoff, F.M. , Phang S.M. K.J., and Mohamed, S. (1997). Nutritional values of chironomid larvae grown in palm oil mill effluent and algal culture. *Aquaculture,* 158: 95-105.

Hameed, B.H., Ahmad, A.L., and Hoon, N. (2003).Removal of residual oil from palm oil mill effluent using solvent extraction method. *Journal Technology*. 33- 42.

Hansen, B., Alroe, H.F.,and Kristensen, E.S. (2001). Approaches to assess the environmental impact of organic farming with particular regard to Denmark. Agriculture, Ecosystems and Environment, 83(1-2): 11-26.

Hartenstein, R., and Hartenstein,F. (1981). Physicochemical changes effected in activated sludge by the earthworm Eisenia foetida. *J. Environmental Quality*, 10: 377.

Hartley, C.W.S. (1988). The products of the oil palm and their extraction. Oil palm 3rd ed. *Longman Scientific and Technical with John Wiley and Sons, Inc. New York: Pp. 721-724.*

Hemming, M.L. (1977). Available solution to the palm oil effluent problems. In: Proceedings of the Malaysian International Symposium on Palm Oil Processing and Marketing. D.A, Earp and W. Newall (eds.): *Kuala Lumpur, 17-19th: Pp. 79-95.*

Hillel, D. (1982). Introduction to soil physics. *Academic Press, San Diego, CA.*

Hojjat, M., and Salleh, M.A.M. (2009). Optimization of POME Anaerobic Pond.*J. European Scientific Res*., 32: 455-459.

Huan, K. L. (1987). Trials on Long-term Effects of Application of POME on Soil Properties, Oil Palm Nutrition and Yields. In : Proceedings of the International Oil Palm, Palm Oil Conferences (eds.) B. Hj. Abdul Halim, Hassan Chew Poh Soon, B.J. Woond; E. *PushParajah (eds.)* 2:575 – 598.

Hui, Y.H. (1992). Encyclopedia of food Science and Technology, *John Wiley and Sons Inc; Vo*l.3, pp: 1992-1994.

Hwang, T.K., Ong,S.M., Seow ,C.C.,and Tan, H.K. (1978). Chemical composition of palm oil mill effluents. *Planter, 54: 749-756.*

Jackson, M.L. (1965). Soil Chemical Analysis - Advanced Course. *Department of Soils, University of Wisconsion, Wisconsin, USA.*

Ijioma, M. A., and Arunsi, S.I. (1990). "Climatic Characteristics" in U.M. Igbozurike (ed), Socio-Economic Development of Orlu. *Owerri: Kartopress*. Pp. 15-21.

Ipek, U., Obek, E., Akca,L., Arslan, E.I. Hasar,H., Dogru,M., and Baykara,O. (2002). Determination of degradation on radioactivity and its kinetics in aerobic Composting. *Bioresource Technol*.,84: 283-286.

James, R.,Sampath, K., and Alagurathinam, S. (1996).Effects of lead on respiratory enzyme activity, glycogen and blood sugar levels of the teleost *Oreochromis mossambicus* (Peters) during accumulation and depuration. *Asian fisheries science. Metro Manila*, 9(2): 87-100.

Keu, S.T. (2005). Review of previous similar studies on the environmental impacts of oil palm plantation cultivation on people, soil, water and forests ecosystem MSc. Thesis. *Faculty of Horticulture, China University*, pp: 1-12.

Khalid, A.R., and Mustafa, W.A.W. (1992). External benefits of environmental regulation: Resource recovery and the utilisation of effluents. *The Envir*.,12(4): 277-285.

Khan, M.A.I., Ueno,K., Horimoto, S., Komai, F., Tanaka, K., and Yoshitaka, O. (2009).Physicochemical, including spectroscopic and biological analyses during composting of green tea waste and rice bran. *Biology and fertility of soils*, 45: 305-313.

Khoo, K.L., and Chew, P.S. (1979). Mulching in oil palm area with empty bunches. *Selango planters Assoc. Ann*. Rep. Pp. 35-40.

Kwon, G. S., Kim, B.H.,and Ong, A.S.H. (1989). Studies on the utilization of palm oil wastes as the substrates for butanol fermentation. *Elaeis* 1 (2): 91-102.

Lim, C.A., and P'ng, T.C. (1983). Land application of digested POME by sprinkler system. Proceedings of the seminar on land application of oil palm and rubber factory effluent. *Serdang, October*, 1983.

Linke, B. (2006). Kinetic study of thermophilic anaerobic digestion of solid wastes from potato processing. *Biomass and Bioenergy, 30: 892-896.*

Longsdon, G. (1994). Worldwide progress in vermicomposting. *Biocycle*, 35:63-65.

Loong, S.G., Mazeeb, M., and Letchumana, A. (1987). Optimizing the use of EFB mulch on oil palms on two different soils. PORIM International Palm Oil Development Conference. *Kuala Lumpur, Malaysia. Abst.Pp.24.*

Lorestani, A.A.Z. (2006). Biological treatment of palm oil effluent (POME) using an up-flow anaerobic sludge fixed film (UASFF) bioreactor [TD899. P4 L869 2006 f rb].

Lumbricus Terrestris Butt, K.R., (1993). Utilisation of solid paper-mill sludge and spent brewery yeast as a feed for soil-dwelling earthworms. *Bioresource technol.*, 44: 105-107.

Macci, C., Masciandaro,G., and Ceccanti,B .(2009).Vermicomposting of olive oil mill wastewaters. *Waste Manage Resources,* 28(8): 738.

Ma, A.N., (2000). Environmental management for the oil palm industry. Palm Oil. Dev., 30:1-10.

Macheswaran, A .,and Singam, G. (1977). Pollution control in the palm oil industry- promulgation of regulations. *Planter* 53:470-476.

Mohammad, A.W., Wu, T.Y., Jahim, J., and Anuar, N. (2009). A holistic approach to managing palm oil mill effluent(POME): Biotechnological advances in the sustainable reuse of POME. *Biotechnology Advances* 27(1): 40-52.

Muhrizal, S., Shamshuddin, J., Fauziah, I., and Husni, M.A.H. (2006). Changes in iron-poor acid sulfate soil upon submergence. *Geoderma,* 131: 110-122.

Nagavallemma, K.P., Wani, S.P. , Stephane, P.V.V. , Lacroix, C., Vineela , M., Babu rao and Sahrawat, K.L. (2004). Vermicomposting: Recycling wastes into valuable organic fertilizer. *Global Theme on Agrecosystems Report.*

Nawawi Mohd, M.G., Othman, N.,Sadikin, A.N., Khalid, S.S,. and Yusof, N. (2008). Development of empty fruit bunch filter with addition of chitosan for pre-treatment of palm oil mill effluent. *J. Chemical Natural Resources Eng*., 2: 8-16.

Nelson, D.W., and Sommers, L.E. (1982). Total carbon, organic carbon and organic matter. P. 53-579. In: A. L. Page et al. (ed.) Methods of soil analysis: Part 2. Chemical and microbiological properties. *ASA Monograph Number 9*.

Ndegwa, P.M., and Thompson, S.A. (2001). Integrating composting and vermicomposting the treatment and bioconversion of biosolids. *Bioresource Technoogy*.,76: 107-112.

Ngan, M.A., Zajima, Y., Asahi, M .,and Junit, H. (1996). A novel treatment process for palm mill effluent. *PORIM.*

Obi, C. I., Onweremadu, E. U., and Obi J. C. (2011). Effect of Palm Oil Milling Wastes on the Physico-chemical Properties of Soils in Okija, South-eastern Nigeria. Agro-science: *Journal of Tropica l Agriculture, Food, Environment and Extension,* 10 (2): 42-48.

Odu, C. T. I., & Mba, C. C. (1991). Microbiological Consideration for Maximizing Nutrient Availability through Organic Fertilization. *Proceedings of a National Organic Fertilizer Seminar (pp. 67– 80). Kaduna, Nigeria.*

Ofomata, G.E.K. (1975). Land form regions. In: Ofomata G.E.K (ed.) Nigeria in Maps: Eastern States. Benin City : *Ethiope Publishing House*, pp. 33 34.

Okwute, L. O., and Isu, N. R. (2007). The Environmental Impact of Palm Oil Mill Effluent (POME) on some Physico-Chemical Parameters and Total Aerobic Bioload of Soil at a Dump Site in Anyigba, Kogi State, Nigeria. *African Journal of Agricultural Research*, 2 (12): 656-662

Olsen SR., and Sommers L.E. (1982). Phosphorus In: A. L. Page, R.H. Miller And D.R. Keeney (eds.) Methods of Soil Analysis, Part 2, Chemical and Microbiological Properties. *Madison, Wisconsin* : pp. 403-430.

Onyia, C.O., Uyub, A.M., Akunna,J.C., Norulaini, N.A., and Omar, A.K.M. (2001). Increasing the fertilizer value of palm oil mill sludge:bioaugmentation in nitrification. Sludge Management Entering the Third Millenium-Industrial, Combined, Water and Wastewater Residues*,* 44: 157-162.

Ordoñez, C., Tejada, M., Benitez, C., and Gonzalez, J.L. (2006). Characterization of a phosphorus-potassium solution obtained during a protein concentrate process from sunflower flour. Application on rye-grass*, Bioresource Technol*., 97: 522-528.

Ortiz, R.A., Villalobos, E., and Fernundez, O. (1992). Mulch and Fertilizer Effect on Soil Nutrient Content, Water Contamination and Oil Palm Growth. *ASD Oil Palm Papers, Number* 6.

Osemwota, O. I. (2010). Effect of Abattoir Effluent on the Physical and Chemical Properties of Soils. *Environ Monit Assess*, 167:399–404.

Oswal, N., Sarma, P.M., Zinjarde. S.S., and Pant, A. (2002). Palm Oil Mill Effluent Treatment by a Tropical marine Yeast. *In: Bioresearches Technology, Volumes* 85, *Issue* 1, October 2002, Pp 35-37.

Patricia, A., Dusen, D., Lundy,J., and Gliessman, S.(1991). Integrating social, environmental, and economic issues in sustainable agriculture. *American Journal of Alternative Agriculture*, 6: 34-39.

Paul, E.A., and Clark, F.E. (1989). Soil Microbiology and Biochemistry. *Academic Press Incorporated San Diego, California.* pp.11-234.

Perez, M., Romero, L.I., and Sales, D. (2001). Organic matter degradation kinetics in an anaerobic thermophilic fluidised bed Bioreactor. *Anaerobe*, 7: 25-35.

Quah, S.K., Lim, K.H., Gillies, D., Wood, B.J., and Kanagaratnam,J. (1982). Proc. Regional Workshop on Palm Oil Mill Technology and Effluent Treatment, *PORIM, Kuala Lumpur*, 193-200.

Raymond Miller, W., and Roy Donahue, L. (1992). Soils: An Introduction to Soil and Plant Growth, 6th ed. *Prentice-Hall, Inc. Englewood Cliffs N.J, U.S.A.*

Rincón, B., Raposo, F., Domínguez, J.R., Millán, F., Jiménez, A.M., Martín, A., and Borja, R.(2006). Kinetic models of an anaerobic bioreactor for restoring wastewater generated by industrial chickpea protein production. *International Biodeterioration and Biodegradation*, 57: 114-120.

Rosnah, M.Y., Ghazali, A.,Wan Rosli, W.D., and Dermawan,Y.M.(2010). Influence of Alkaline Peroxide Treatment Duration on the Pulpability of Oil Palm Empty Fruit Bunch. *World Appl. Sci. J.,* 8(2): 185-192.

Rupani, P. F., Singh, R. P., Ibrahim, M. H., and Esa, N. (2010). Review of Current Palm Oil Mill Effluent (POME) Treatment Methods: Vermicomposting as a Sustainable Practice. *World Applied Sciences Journal Article* 10(10): 1190-120.

Sabrina, D.T., Hanafi, M.M., Muhmud, T.M.M.M and Nor azwady,A.A.(2009). Vermicomposting of Oil Palm Empty Fruit Bunch and its potential in supplying of nutrients for crop growth. Compost science and utilization, 17(1): 61-67.

Schuchardt, F., Wulfert, K., Darnoko,D., and Herawan,T .(2007). Effect of new Palm oil mill processes on the EFB and POME utilisation. Proceedings of Chemistry and Technology Conference PIPOC 2007, *Kuala Lumpur*, 26-30 August 2007.

Sethupathi, S. (2004). Removal of Residues oil from palm oil mill effluent (POME) using Chitosan, *Universiti Sains Malaysia*.

Singh, R.P., Hakimi Ibrahimm, M.,and Esa Norizan (2010).Composting of Waste from palm oil mill: A sustainable waste management practice. Review in Environmental Science and Biotechnology, *DOI*: 10.1007/s11157-010-9199-2.

Soil Survey Staff (1999). Soil taxonomy., a basic system of soil classification For making and interpreting soil surveys (2nded.). *Washington, DC US Department of Agriculture Soil Conservation Service*.

Stanton, W.R. (1974). Treatment of effluent from palm oil factories. *Planter*, 50: 382-387.

Sulaiman, A. (2010). Accelerated Start-up of a Semi commercial Digester Tankreating Palm Oil Mill Effluent with Sludge Seeding for Methane Production. *World Appl. Sci. J.*, 8(2): 247-258.

Tabatabai, M.A. (1982). Soil enzymes. In: A.L page RH Miller and DR Reeny (eds). Methods in soil analysis, part 2, *Wisconsin. Am. Soc. Agro, Soil Sci*. 903 – 947.

Tam, N.F.Y., and Tiquia, S.M. (1994). Assessing toxicity of spent pig litter using aseed germination technique. Resource Conservation and Recycling,11: 261-274.

Thomas, G.W. (1982). Exchangeable Cations. In: A.L. Page, R.H. Miller and D.R. Keeney (eds.) Methods of Soil Analysis, Part 2, Chemical and Microbiological Properties. *Madison, Wisconsin*. pp.159-165.

Torres, R., Chinchilla, C., and Ramirez, C. (1999). Compostaje de los desechos agroindustriales de la palma aceitera, Pp. 411-418. In: F. Bertsch; J. Garcia; G. Rivera; F. Mojica; W. Badilla (eds). XI congreso Nacional Agronomico de Recursos Naturales. *UNED, San Jose, Costa Rica.*

U.S. Salinity Laboratory Staff (1995). L.A. Richards (ed). Diagnosis and improvement of saline and alkaline soils. *USDA Handbok.* 60. *U.S Govt. Printing Office, Wash. DC.*

Wambeck, N. (1999). An introduction to Refining process for Palm Oil and other downstream process (*A paper downloaded from internet web pages).*

Wilding L.P., Bouma, J.,and Boss ,D.W.(1994). Impact of Spatial Variability on Interpretative Modelling. In: Bryant R.B. and R.W. Arnold- Quantitative Modeling of Soil Forming Process. *SSSA Special Publ.,* No. 39: 61-75.

Wood, B.J., Pillia, K.R. and Rajaratnam, J.A. (1979). Palm oil mill effluent disposal on land. *Agricultural Wastes* 1: 103-127.

Wood, B.J., Pillai, K.R., and Rajaratnam, J.A. (2003). Palm Oil Mill Effluent Disposal on land. *Chemara Research Station, Seremban,* Malaysia.

Wu T.Y.,Mohammad, A.W.,Jahim, J.,and Anuar, N.(2009). A holistic approach to managing palm oil mill effluent (POME): Biotechnological advances in the sustainable reuse of POME. *Biotechnology Advances*, 27(1).

Wood, B.J. (1977). A review of current methods for dealing with palm oil mill effluents. *Planter* 53:477-495.

Yacob, S., Shirai, Y.,Hassan, M.A.,Wakisaka, M.,and Subash,S. (2006). Start-up operation of semi-commercial closed anaerobic digester for palm oil mill effluent treatment. *Process Biochemistry,* 41: 962-964.

Yaser, A.Z., Rahman, R.A., and Kalil, M.S.(2007). Composting of palm oil mill sludge-sawdust. *Pakistan Journal of biological sciences, PJBS*, 10: 4473.

Zahrim, A.Y., Rachel,F.M., Menaka,S., Su,S.Y.,Melvin,F., and Chan, E.S. (2009). Decolourisation of Anaerobic Palm Oil Mill Effluent via Activated Sludge-Granular Activated Carbon. *World Applied Sciences J. Volume 5 (Special Issue for Environment),* pp: 126- 129.

Zakaria, Z.Z., Khalid, H., and Hamdan, A.B. (1994).Guidelines on land application of palm oil mill effluent (POME). *PORIM Bull Palm Oil Res. Inst.* Malaysia*,* pp: 28.

APPENDICES

Appendix 1: Soil Physical and chemical Properties under various depths and conditions in the study area

	pH	Ca	Mg	K	Na	P	OC	N	Sand	Silt	Clay	MC	EC	SO_4^{2-}
		--------$CMolkg^{-1}$--------				ppm	----------------------%----------------------						µs/cm	
0-15 cm														
Control	6.90	0.90	0.33	0.04	0.03	9.37	1.92	0.04	82.52	7.56	9.92	5.60	53.4	36
Polluted (across 300 m distance)	6.69	5.13	1.59	0.06	0.04	14.85	2.54	0.05	82.77	8.40	8.83	9.56	135.4	56.75
15-30 cm														
Control	6.20	0.80	0.20	0.03	0.02	7.40	1.20	0.04	76.52	5.56	17.92	7.43	46.20	29.00
Polluted (across 300 m distance)	6.66	5.71	0.60	0.05	0.03	12.84	2.12	0.04	78.52	13.06	8.42	8.82	100.9	47.00
Control Site														
0-15	6.90	0.90	0.33	0.04	0.03	9.37	1.92	0.04	82.52	7.56	9.92	5.60	53.40	36.00
15-30	6.20	0.80	0.20	0.03	0.02	7.40	1.20	0.04	76.52	5.56	17.92	7.43	46.20	29.00
Polluted Site														
0-15	6.69	5.13	1.59	0.06	0.04	14.85	2.54	0.05	82.77	8.40	8.83	9.56	135.4	56.75
15-30	6.66	5.71	0.60	0.05	0.03	12.84	2.12	0.04	78.52	13.06	8.42	8.82	100.9	47.00

OC- Organic carbon, N- Nitrogen, SO_4^{2-}- Sulphate, Ca- Calcium, Mg- Magnesium, K- Potassium, Na- Sodium, P- Phosphorous, MC- Moisture content, EC- Electrical conductivity.

Appendix 2: Levels of Physicochemical Parameters of POME from the Study Area.

Parameters	Palm Oil Effluent @ Engine room	Palm Oil Effluent @ Effluent pit
pH	4.5	4.8
Electrical Conductivity, µS/cm	224.0	268.5
Total Dissolved Solids, mg/dm^3	129.44	155.57
Total Suspended Solids, mg/dm^3	205515	21440
Total Acidity, mg/dm^3	6.0	8.0
Phosphate, mg/dm^3	5.05	6.27
Sulphate, mg/dm^3	12.72	11.55
Nitrate-Nitrogen, mg/dm^3	32.5	37.25
B OD, mg/dm^3	10070	11050
Dissolved Oxygen, mg/dm^3	7.11	8.01
COD, mg/dm^3	13440	14110
Oil & Grease, mg/dm^3	8770	9550
Calcium, mg/dm^3	10.71	11.01
Magnesium, mg/dm^3	7.14	8.77
Potassium, mg/dm^3	13.22	14.05

Appendix 3: Descriptive Statistics of Soil Properties of the Polluted Site

Variable	SD	Skewness	Kurtosis	Mean	Median	Min.	Max.	CV
OC (%)	0.64	1.70	4.22	2.33	2.28	1.56	3.75	27.48
N (%)	0.01	1.03	1.85	0.04	0.04	0.03	0.06	20.86
SO_4^{2-}mg/kg	10.96	-0.21	-0.86	51.88	55.00	35.00	68.00	21.13
Ca (Cmol/kg)	4.30	1.04	0.81	5.42	4.55	1.00	13.80	79.29
Mg (Cmol/kg)	1.34	2.58	6.88	1.09	0.59	0.33	4.34	122.85
K (Cmol/kg)	0.01	-0.31	2.21	0.05	0.05	0.03	0.07	21.97
Na (Cmol/kg)	0.01	1.00	-1.04	0.04	0.03	0.03	0.05	25.27
P (ppm)	2.13	-0.26	0.29	13.84	13.85	10.14	16.70	15.39
Sand (%)	4.26	-1.58	2.86	80.65	82.02	71.52	84.52	5.28
Silt (%)	4.10	-0.06	-0.17	10.73	10.06	3.92	16.56	38.24
Clay (%)	5.21	1.36	0.97	8.63	5.92	4.92	18.92	60.38
pH	0.55	-1.11	-0.15	6.68	6.94	5.68	7.20	8.28
MC	1.88	0.96	0.31	9.19	8.94	7.34	12.73	20.45
EC (µS/cm)	69.23	0.75	0.48	118.16	98.25	19.10	239.90	58.59

OC- Organic carbon, N- Nitrogen, SO_4^{2-}- Sulphate, Ca- Calcium, Mg- Magnesium, K- Potassium, Na- Sodium, P- phosphorous, MC- Moisture content, EC- Electrical conductivity, SD- Standard deviation.

Appendix 4: Descriptive Statistics of Soil Properties of the Control Site

Variable	SD	Mean	Median	Min.	Max.	CV
OC (%)	0.51	1.56	1.56	1.20	1.92	32.64
N (%)	0	0.04	0.04	0.04	0.04	0
SO_4^{2-}mg/kg	4.95	32.50	32.50	29.00	36.00	15.23
Ca (Cmol/kg)	0.07	0.85	0.85	0.80	0.90	8.31
Mg (Cmol/kg)	0.09	0.27	0.27	0.20	0.33	34.69
K (Cmol/kg)	0.01	0.04	0.04	0.03	0.04	20.20
Na (Cmol/kg)	0.01	0.03	0.03	0.02	0.03	28.28
P (ppm)	1.39	8.39	8.39	7.40	9.37	16.61
Sand (%)	4.24	79.52	79.52	76.52	82.52	5.34
Silt (%)	1.41	6.56	6.56	5.56	7.56	21.56
Clay (%)	5.66	13.92	13.92	9.92	17.92	40.64
pH	0.49	6.55	6.55	6.20	6.90	7.56
MC	1.29	6.52	6.52	5.60	7.43	19.86
EC (μS/cm)	5.09	49.80	49.80	46.20	53.40	10.22

OC- Organic carbon, N- Nitrogen, SO_4^{2-}- Sulphate, Ca- Calcium,
Mg- Magnesium, K- Potassium, Na- Sodium, P- phosphorous,
MC- Moisture content, EC- Electrical conductivity, SD- Standard deviation.

Appendix 5: Section of the Study Site.