

**Investigation of the accumulation effects of heavy metals in oil
palm plantation soils fertilized with anaerobically treated
palm oil mill effluent in southern Nigeria**

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Abstract

The accumulation of heavy metal in oil palm plantation soils is a growing concern due to its potential environmental and health implications. This study aimed to investigate the accumulation of heavy metal on oil palm plantation soil fertilized with palm oil mill effluent POME. The research appraised the extent of contamination in oil palm plantation soil in Ikpoba Okha local government area of Edo state Nigeria. Soil samples were collected from different soil depth ranges 0-15cm, 15-30cm, 30-45cm, 45-60cm and 60-70cm of POME treated soil at five locations (2-6) and the control location 1 within oil palm plantations. The concentrations of the heavy metals (Cu, Mn, Zn, Ni, Pb, Cd, Cr, As, Hg) were analyzed using the atomic absorption spectrometry (AAS). The results show that the application of POME as fertilizer led to increased concentration of heavy metals. Significant difference at ($p < 0.05$) level in concentration was obtained across the different depths of the treated locations for the metals compared to the background location. However, As and Hg were not significantly different between the POME treated soil and control location. The impacts of POME treatment have greater effects on the concentration of the essential metal (Cu, Mn, Zn, Ni) compared to the non-essential metal (Pb, Cr, Cd, As, Hg). The concentration of the metals was below the permissible limits of regulatory standards. The increase in concentration of the essential metal could have potential implications of soil contamination due to accumulation over time. The soil had contamination factor and pollution load index of low to moderate contamination and pollution. The control location 1 had the closest similarity with the location 6. The study proposed a recommendation for POME usage as organic fertilizer in agricultural soil but with close monitoring.

Abstract (Deutsch)

Die Anreicherung von Schwermetallen in den Böden von Ölpalmenplantagen gibt aufgrund ihrer potenziellen Auswirkungen auf Umwelt und Gesundheit zunehmend Anlass zur Sorge. Ziel dieser Studie war es, die Anreicherung von Schwermetallen in Ölpalmenplantagenböden zu untersuchen, die mit Palmölmühlenabwässern (POME) gedüngt wurden. Im Rahmen der Studie wurde das Ausmaß der Kontamination von Ölpalmenplantagenböden in Ikpoba Okha im Bundesstaat Edo in Nigeria untersucht. An fünf Standorten (2-6) wurden Bodenproben aus verschiedenen Tiefenbereichen (0-15 cm, 15-30 cm, 30-45 cm, 45-60 cm und 60-70 cm) von mit POME behandeltem Boden und dem Kontrollstandort 1 innerhalb der Ölpalmenplantagen entnommen. Die Konzentrationen der Schwermetalle (Cu, Mn, Zn, Ni, Pb, Cd, Cr, As, Hg) wurden mit Hilfe der Atomabsorptionsspektrometrie (AAS) analysiert. Die Ergebnisse zeigen, dass die Anwendung von POME als Düngemittel zu einer erhöhten Konzentration von Schwermetallen führte. In den verschiedenen Tiefen der behandelten Standorte wurde ein signifikanter Unterschied ($p < 0,05$) in der Konzentration der Metalle im Vergleich zu den Hintergrundstandorten festgestellt. Bei As und Hg gab es jedoch keine signifikanten Unterschiede zwischen dem mit POME behandelten Boden und dem Kontrollstandort. Die Auswirkungen der POME-Behandlung haben größere Auswirkungen auf die Konzentration der essentiellen Metalle (Cu, Mn, Zn, Ni) im Vergleich zu den nicht-essentiellen Metallen (Pb, Cr, Cd, As, Hg). Die Konzentration der Metalle lag unter den zulässigen Grenzwerten der gesetzlichen Normen. Der Anstieg der Konzentration des essentiellen Metalls könnte aufgrund der Akkumulation im Laufe der Zeit potenzielle Auswirkungen auf die Bodenverschmutzung haben. Der Boden wies einen Kontaminationsfaktor und einen Schadstoffbelastungsindex von geringer bis mäßiger Kontamination und Verschmutzung auf. Der Kontrollstandort 1 wies die größte Ähnlichkeit mit dem Standort 6 auf. In der Studie werden Empfehlungen für die Verwendung von POME als organischer Dünger in landwirtschaftlich genutzten Böden ausgesprochen, allerdings unter strenger Überwachung.

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List of acronyms and abbreviations

AAS	Atomic Absorption Spectrometry
ANOVA	Analysis of Variance
ATP	Adenosine Triphosphate
BOD	Biological Oxygen Demand
CDM	Clean Development Mechanism
CERs	Carbon Emission Reductions
CEC	Cation Exchange Capacity
CF	Contamination Factor
COD	Chemical Oxygen Demand
CNS	Central Nervous System
CSTR	Continuous Stirred Tank Reactor
CVAAS	Cold Vapour Atomic Absorption Spectrometry
DC	Decanter Cake
DC	Degree of Contamination
EFB	Empty Fruit Bunch
EGSB	Expanded Granular Sludge Bed
FAO	Food and Agricultural Organization
FEPA	Federal Environmental Protection Agency
FFA	Free Fatty Acid
FFB	Fresh Fruit Bunch
FRN	Federal Republic of Nigeria
HRT	Hydraulic Retention Time
LSD	Least Significant Difference
MUFA	Mono Unsaturated Fatty Acid
PIND	Partnership Initiative in the Niger Delta
PKC	Palm Kernel Cake
PKO	Palm Kernel Oil
PKS	Palm Kernel Shells
PLI	Pollution Load Index
POME	Palm Oil Mill Effluent

POMS	Palm Oil Mill Sludge
PPF	Palm Press Fibre
PUFA	Poly Unsaturated Fatty Acid
RSPO	Roundtable on Sustainable Palm Oil
SFA	Saturated Fatty Acids
SPO	Special Palm Oil
SPSS	Statistical Package for the Social Sciences
TPO	Technical Palm Oil
UASB	Upflow Anaerobic Sludge Blanket
UK	United Kingdom
USA	United State of America
UV	Ultra Violet
VFAs	Volatile Fatty Acids
WHO	World Health Organization

Chapter 1 Introduction

1 Background study

The world demand for edible vegetable oil continues to grow rapidly with population increase which has led to prominent increase in oil crop cultivation, primarily oil palm (Embrandiri et al., 2015). Among the world's annual production of vegetable oil, palm oil accounts for 37 percent, overtaking soybean oil as the leading edible vegetable oil (Ofusu-Budu & Sarpong, 2015). South-East Asia in Indonesia takes the lead in oil palm production followed by Malaysia and Thailand; all account to 90 percent of global oil palm production (IPPA, 2010). In West-Africa, 3.5 percent is contributed globally with Nigeria at the fore-front (Ofusu-Budu & Sarpong, 2015). In Nigeria, approximately 2.3 million hectares of oil palm were cultivated in 2018 (Statista, 2022). Statista publication in 2022 revealed that 1.4 million metric tons of palm oil was produced in Nigeria in year 2022. The palm oil industrial sector is one of the main and leading agro-economic driving based industries in Nigeria (Ohimain et al., 2012). The Niger Delta states are famous for oil palm production with three main systems of production estimated to occupy 57 percent of the national oil palm area. These systems are large estate, medium/small holder and semi/natural groove which practices subsistent farming generating 80 percent of the oil palm production (PIND, 2011). Three species of oil palm is found in Nigeria namely Tenera, Dura and Pisifera with the Tenera having over 80 percent of the species found in Nigeria and the highest oil yield (Izah, et al., 2016).

However, the aftermath of processing of the fresh fruit bunch (FFB) of oil palm generates three kinds of waste such as solid, liquid and gaseous waste (Ohimain & Izah, 2014). The solid waste proceeds from this industry include 21-31 percent of empty fruit bunches (EFB), 10-28.5 percent of palm press fiber and 5-18 percent of palm kernel shell per fresh fruit bunch (Izah et al., 2016). Gaseous emissions include oxides of nitrogen and Sulphur, carbon monoxide, volatile organic matter and suspended particulate matters which are emitted during the combustion activities in the mill (Rupani et al., 2010). Large amounts of liquid waste called palm oil mill effluent (POME) is generated from the palm oil mill industry due to the large amount of water needed to process the oil palm fruit in

the mill. This water is used in the sterilization of the FFB, clarification of the crude palm oil and hydro cyclone separation of the kernels with hot steam (Ohimain & Izah, 2014). The palm oil mill is expected to discharge 0.7-1.0 cubic meter of POME for every ton of FFB produced with about 5-7.5 tons of water utilized (Rahayu et al., 2015). In Nigeria POME is usually discharged by local palm oil mill operators into water bodies which could lead to biodiversity loss and death of aquatic organism as a result of oxygen depletion (Okwute & Isu, 2007). Odor emanating from POME discharge into the environment is another source of pollution (Rahayu et al., 2015). It has been reported by Ohimain and Izah (2014) that POME discharged into the environment contributes immensely to global warming due to greenhouse gases emitted such as carbon dioxide and methane.

In search of sustainable management of the waste produced from the huge and fast-growing palm oil industry, there is need for better agro-industrial sustainable practice in order to reduce the environmental impact of oil palm processes. Conversion of organic waste to energy using anaerobic digestion treatment seems to proffer solution to reduce the environmental impact, generating renewable energy and organic manure concurrently (Rahayu et al., 2015). Anaerobic digestion treatment occurs in the absence of oxygen and is typically applied in POME sludge to energy processing. These treatment processes work better economically to produce high levels of biogas and treated effluent compared to the aerobic treatment process. Palm oil plantation owners utilize this treated water rich in nutrients such as nitrogen, phosphorus, and potassium for fertilization of the plantation. Anaerobic digestion treatment process takes place in four stages namely hydrolysis, acidogenic, acetogenic and methanogenic (Izah et al., 2016).

Several agro-processing industries have been provided with carbon credit incentives to develop methane capture installation like biogas plants to mitigate climate change impacts via carbon emission reductions (CERs) (Mahananda, 2015). In Nigeria, sustainable development is gaining gradual significance as opportunity abounds for successful implementation of a CDM projects. There is increase acknowledgement on the bountiful opportunities of the CDM project activities in a mill by plantation owners. Approximately total of 12 Clean Development Mechanism (CDM) projects have been installed with land fill gas and fugitive emission reduction given utmost priority at the

moment (Pillay, 2016). The benefit of utilizing the methane capture from the biogas plant for electricity and organic manure generation have attracted many palm oil mills industrial sector.

Palm oil mill effluent sludge from the biogas plant after treatment contains high concentration of organic matter with high moisture and nutrient which could enhance soil fertility (Rupani et al., 2010). The Useful amount of nitrogen, phosphorus, potassium, and calcium which are vital ingredient for plant growth used in fertilizer industries are contain in the sludge. Numerous Studies have proved the significant effect of palm oil mill effluent sludge as organic fertilizers. Palm oil mill sludge from biogas reactor contain abundant quantities of solids, both suspended solids and total dissolved solids. The suspended solids are in the range of 18000mg/l while the dissolved solid is 40000mg/l. The volume and weight of the sludge can be reduced to make it suitable compost to manure the plantation (Ohimain & Izah, 2014). Most importantly, the low level of heavy metal elements in the sludge makes it safe to be used as organic fertilizers.

However, the long-term use of palm oil mill effluent sludge on agricultural soils pose danger of heavy metal contamination or pollution. Soils contamination challenge are mainly that of heavy metal. This is due to the non-degradable, bioaccumulation, toxicity and persistency properties of the metals. Also, soil chemical properties such as pH, organic carbon, cation exchange capacity (CEC) are vital determinant of the mobility, toxicity accumulation and the entire significance of the heavy metal in the soil (Shakery et al., 2010). The presence of heavy metal contaminant in soils at concentration more than the background levels may demonstrate a high potential soil health and ecological risk. These metals can further pose a significant threat to human health via food chain. Studies have shown that heavy metal concentration and contamination in soil is influenced by nature of the soil parent material and human induced anthropogenic activities such as commercial fertilizer input, organic manure applications, irrigation water from industrialized area etc. For instance, most commercial farmers rely on fertilizers application in soil to have a robust harvest. In Nigeria, gradual transformation in economic and industrial growth have been observed over the decades. Increase pollution from petroleum, mining and agro-processing industries have been on the rise (Onakpa et al., 2018). (Idowu, 2022) reported that about 2 million people in Niger Delta region of

Nigeria could become victim of heavy metal poisoned by Lead, mercury, cadmium proceed from these industries. Studies have proved that concentration of trace metals in some crops harvested in the Niger Delta region such as oil palm is higher compared to standards. This outcome calls for concern due to bioaccumulation properties of these metals upon consumption of this crop which in turn affects human health. Unfortunately, there are absence of food diaries in Nigeria to monitor heavy metal intake. (Onakpa et al., 2018)

Heavy metal accumulation in oil palm plantation soils via consistent ferti-irrigation with palm oil mill sludge may result in soil contamination increasing the total amount of copper, zinc, lead, cadmium, Manganese and mercury in the soil (Ramamoorthy, 2015). The negative effects of this metals on the environment and human health birth the importance to clarify the status of fertilized agricultural soils and quantify their metal concentrations.

1.1 Statement of the problem

Agricultural induced activities such as the use of organic fertilizers and irrigations could substantially alter the soil quality and affect the ecosystem process (Bai, et al., 2018). Deliberate and long-term application of organic fertilizers to oil palm plantation soils to boost the crop production in order to meet the growing human demands over the decades have resulted to soil health contamination with heavy metals (Nkwunonwo et al., 2020). The introduction of organic fertilizers such as palm oil mill effluent sludge can alter the soil properties such as pH and cation exchange capacity (CEC). Heavy metal occurring naturally in the soil through weathering of soil parent material can as well be increased through these anthropogenic acts.

Numerous studies on strategies and approaches to restrain heavy metal contamination in the soil because of these anthropogenic induced acts have been carried out. However, there has been no sustainable human practices without counter reactions of soil contaminations of various kinds especially with heavy metals. These inadequacies present a challenge for agro-industry due to adverse effect of these metals on soil health (Nkwunonwo et al., 2020). It is therefore imperative to undertake this study and quantify heavy metals' status in agricultural soil induced with this human practice.

1.2 Research questions

With respect to the problem statement, the following questions were discovered to guide the study.

- I. How sustainable to the oil palm plantation is anaerobically treated POME sludge for ferti-irrigation?
- II. What is the extent of heavy metal accumulation in soil after the application of POME as fertilizers?
- III. What are the potential sources of heavy metals in POME and how do they contribute to the overall heavy metal content in the soil?

1.3 Research significance

This study will contribute to the body of knowledge in management of industrial waste such as POME and sustainable soil management practices in the agro-industries in general and oil palm industries as case study.

The study will help to assess the environmental impact of POME usage in agricultural soil which can help to preserve the soil health. It will also aid in policy making that will guide and regulate safe use of POME. This can be achieved through the data and evidence obtained.

1.4 Research aim and objectives

Due to lack of sustainable soil management treatment in oil palm agro industry, the study aims to investigate and evaluate oil palm plantation soil contamination with heavy metals via the use of anaerobic treated palm oil mill effluent as manure with a plantation in Edo, a Niger Delta state in southern Nigeria as a case study. To attain this aim, three objectives were developed as follows:

- I. To find out the concentrations of heavy metals in the plantation soils and the observed differences between the concentration in the soils.
- II. To investigate the possible degree of contamination and pollution of the plantation soil.

- III. To evaluate the spatial variation of the concentration with regards to locations.

1.5 Research hypothesis

Oil palm plantation soil treatment with anaerobically digested palm oil mill effluent for ferti-irrigation has no heavy metal accumulation effect in the soil.

1.6 Thesis Structure

This study has seven chapters starting with the introduction chapter one that lay out the background into the study and show case the road map of what to expect in this dissertation. The introduction also provides the research aim, objectives questions and significance of the study.

Chapter two discusses the oil palm cultivations, palm oil production systems in Nigeria, benefits of the oil palm industry, oil palm market systems, palm oil extraction processes and methods and the characteristics of the palm oil.

Chapter three explains in details the waste generated from the palm oil industry from solid to gaseous waste type, palm oil mill effluent and its characteristics, management of the effluent with anaerobic digestion treatment process and the technology engaged, palm oil mill sludge characteristics and management.

Chapter four presents the heavy metals and the soil type obtainable across Nigeria geopolitical zones, the anthropogenic source of the heavy metal and the remediation techniques applied in heavy metal polluted sites and the soil management practices in Nigeria.

Chapter five describes the materials and methodology engaged in this study, brief description of the study area with the climatic features, soil sampling technique and soil collection, laboratory analysis, quantitative data analysis and contamination factor and pollution load index.

Chapter six is the result and discussion. This chapter presents the analyzed data using tables and charts where applicable. The soil data was analyzed using analysis of variance and Fishers least significant difference post hoc test. Contamination factor, degree of contamination and pollution load index equations were engaged to determine the extent of the contamination and pollution in the soil.

Chapter 2

2 Oil palm cultivation

The oil palm is the richest oil-bearing crop in terms of yield efficiency. About four tonnes of crude palm oil can be obtained per hectare of plantation (Saifuddin et al., 2017). The oil palm tree (*Elaeis guineensis*) which originated from West Africa belongs to the *Arecaceae* family (Mba et al., 2015). Oil palm has three species namely, Dura, Pisifera and Tenera. Tenera is the crossbreed of Dura (female specie) and Pisifera (male specie) which is the most commercially accepted. Dura has thin mesocarp and thick endocarp. Pisifera has thick mesocarp but with small oil and absence of endocarp with little kernel. Tenera has a thick mesocarp with high oil content and a thin endocarp with kernel moderate in size. (Aba & Baiyeri, 2012) Two types of oil are obtained from the oil palm crop namely; palm oil and palm kernel oil. While the palm oil is obtained from the crop mesocarp, the palm kernel oil is obtained from the oil palm seed (Aba & Baiyeri, 2012). The tropical perennial crop grows in a warm environment with adequate soil moisture all through the year. (Goh et al., 2017). Oil palm trees have a life span to maximum of about 150 years. The tree grows above the soil up to 30-40-meter-high and root grows down the soil up to 1 meter (Goh et al., 2017). Optimal temperature of between 30-32 degree Celsius is required for the cultivation of the crop. Temperature below 20 degrees Celsius and above 40 degrees Celsius are not suitable for growing oil palm. The plant flourish between 2500 to 4000 milli meter per annum of rainfall. Where this is not possible, irrigation practice can meet the water demand of the tree. A daily bright sunshine of 5-6 hours and 75 to 100 percent humidity is suitable for proper development of the oil palm plantation. Soil characterized with rich organic matter with sufficient soil moisture and pH between 4.0-6.8 are appropriate for oil palm growth and development (Goh et al., 2017).

Oil palm seed treatment is vital in oil palm cultivation. The germination of oil palm seed is tedious and heat demanding. Under normal circumstances, the germination of oil palm seed takes between 1 to 3 years before germination. This dormancy in seed could be due to factors such as embryo immaturity, impermeability of the seed coat or

physiological event during storage. To speed up the time rate of germination, three methods may be required namely; use of chemical agent, mechanical scarification or heat treatment depending on the progeny. Heat treatment is the most engaged method to break the dormancy. The seed is dried for about two and a half months in an insulated room with stable temperature of about 38-40 degrees Celsius. The seed are further soaked between 4-5 days in water meant to be changed daily and treated with fungicide to prevent the formation of moulds. Seeds germinate in about 12 days. After germination, sprouts are planted in a polyethylene bag filled with equal amount of top soil sand and manure. The sprouts are left in the bag 4-5 months until a bifil leaf is noticed. The bifil leaf continue to develop in the plantation nursery for about 12 months. Consequently, seedlings which have up to 12-15 leaves are moved to the plantation (Dickson, et al., 2021).

Before planting in the plantation, the soil has to be prepared by weeding, tilling and applying of fertilizer. The raining season; June to September is most suitable planting season for the sprout. The plant sprout is often planted in triangular pattern with a spacing distance of 9 meter apart. About 145 tree of oil palm tree makes up a hectare. Oil palm has high resistance for drought for several months but limited in growth and productivity under this condition. The plant grows best under natural rainfall. When rainfall is not enough, irrigation farming practice is engaged to compensate for shortage of water. Irrigation method such as micro sprinklers, basin and drip irrigation are used to meet the water need of the plant (Priwiratama et al., 2018).

Oil palm plantations are troubled by weed. Constant weeding is required for proper growth and maximum yield of the oil palm. Among the weed disturbing the oil palm, competing with sunlight, moisture and nutrient include; *Chromolaena odorata*, *Aspilla africana*, *Mimosa pudica*, *Clidemia hirta*, *Panicum maximum*, *Nephrolepsis*, *Lantana Camara* etc (Essandoh et al., 2011). Physical removal of weeds and chemical spraying are ways to manage the weed in oil palm plantation.

Oil palm are troubled by both pest and diseases. Among the pest that troubled oil palm are rhinoceros beetles, bagworms, red palm weevils, mealy bugs. Most oil palm disease are wilts and rots. Early detection and timely response is most efficient in pest and disease control in oil palm plantation (Priwiratama et al., 2018).

Fertilizer application in oil palm plantation vary with the tree age. For maximum growth and yield, sufficient and appropriate amount of micro and macro nutrient are required. These include Nitrogen, Potassium, Phosphorus, Magnesium, Calcium etc. Symptoms of Nitrogen deficiency reveals chlorotic leaves. Nitrogen is needed for healthy growing of plants and viable fruit formation (Sanjeevraddi et al., 2016). Premature drying of leaves in older tree foliage are some symptoms of Phosphorus deficiency. Phosphorus increase bunch weight in oil palm and also the female flower. Potassium deficiency results to chlorosis and necrosis. Also orange spot, plant foliage with pale green to yellow coloration are experienced. These deficiencies cause oil palm to wither prematurely and unhealthy (Sanjeevraddi et al., 2016). Studies shows that NPK fertilizer application on palm oil plantation in Karnataka in India on ratio 2:1:2 yielded healthy fruit bunch. Magnesium deficiency results to discoloration in older leaves with bright orange colour (Sanjeevraddi et al., 2016).

Oil palm is ripe to be harvested after 3 years of cultivation. Some sign of maturity of the oil palm is noticed when 4-6 fruits begin to drop down from the fresh fruit bunch. Mature fruit are orange to dark red in colour. Harvesting of matured fruit bunch often times have become challenging to plantation owners. The fresh fruit bunch can be harvested using manual method of matcheting which is tiring and energy consuming. Most small plantation owners lack cutting skills in harvesting of matured FFB. This can be detrimental resulting to self-inflicted injury or loss of life on the person involved in the cutting or persons around. Estate plantation owners use harvesting machine which are more effective, consuming less energy and saves time (Khalid et al., 2014).

The Roundtable on Sustainable Palm Oil (RSPO) in 2004 compelled plantation and mill owners to embrace sustainable practice through minimization of their environmental footprint. RSPO help to minimize the negative consequences with palm oil cultivation, harvesting and waste management of the waste from the industries. Practices such as zero palm oil tree deforestation, control of soil erosion, oil palm surface water quality, heavy metal control, checked by RSPO standards tends to protect and preserve the environment and boost tropical biodiversity. (Herrmann, 2013).

2.1 Palm oil production in Nigeria

Numerous research has cited West Africa as the place where oil palm originated. Nigeria was tagged as the nation where it specifically originated before the 14th century (IPPA, 2010).

In the 19th century, Nigeria palm oil was dominant in the world market. The countries foreign exchange and wealth relied almost totally on palm oil (Eshalomi, 2009). Nigeria's palm oil accounted for 43 percent of world oil palm production until 1960s where declination begin to take place due to total reliance on traditional methods of production (Olagunju, 2008). Moreover, the Nigeria civil war between 1967-1970 also played a major factor in the dwindling oil palm industrial sector in the nation. During this season, viable oil palm trees were destroyed for the reason of palm wine and production rate could not measure up to the world demand (IPPA, 2010).

Nigeria oil palm tree is majorly found in the Niger Delta region and scarcely in the North Central Nigeria state such as Kogi, Kwara, Benue, Niger, Plateau, Taraba and Nasarawa states. Three main categories of oil palm plantation production systems exist in Nigeria, namely, semi/natural groove, small and medium holder plantation and large scale (estate) plantation as shown in table 2 below (IPPA, 2010). Table 1 shows the yield per production system of FFB in metric tons per hectare of land per year. An estate plantation covers a land mass of one hundred hectares and above. Most large estates in Nigeria are owned by either the federal government or state government. The small estates are owned by individuals or cooperatives. While the Medium estate are owned by either state or cooperatives (PIND, 2011).

Oil palm farming in Nigeria is dominated by small holder farmers. Farming by this subsistent farmer usually covers between 1-10 hectares. These farmers practice mixed cropping with oil palm plantation to maximize the farmland usage. Research shows that 80 percent of Nigeria palm oil production is controlled by this subsistent farming practiced by small holders' farmer (Olagunju, 2008).

Table 2 shows the different production system on state basis in the Niger Delta states in Nigeria. From the table, Edo state has the highest number of estate plantation

production while Akwa-Ibom and Cross river state have the highest wild grove plantation of 240,000 hectares.

Table 1: Yield per production systems (fresh fruit bunches/tonnes/hectares/year)

Production system	Hectares	Yields
Wild grove	n.a	1.5 FFB/tonnes/ha/year
Small scale farm	1-10 ha	3 FFB/tonnes/ha/year
Medium scale farm	10-25 ha	3 FFB/tonnes/ha/year
Large scale farm	25-100 ha	5 FFB/tonnes/ha/year
Estate	+100 ha	5 FFB/tonnes/ha/year

Source: (PIND, 2011)

Table 2: Estimated area in hectares under oil palm in different production systems on a state basis in the Niger Delta (PIND 2011)

State	Wild groves	Medium and small-scale holders	Estate plantation
Akwa-Ibom	240,000	32,277	3,096
Edo	50,000	24,542	28,147
Ondo	85,000	10, 143	16,169
Rivers	91,655	57,000	16,300
Cross river	240,000	29,577	26,207
Delta	60,000	13,730	6,246
Abia	150,000	29,765	4,589
Imo	106,690	67,690	3,410
Bayelsa	39,000	2,459	1,212

Source: (PIND, 2011)

Presently, Nigeria is ranked the fifth largest producer of palm oil after Indonesia and Malaysia with an annual production of 1.4 million metric tons (Statista, 2020). Between 2009 to 2015, the highest production was observed in the year 2010 as shown in figure 1. According to research done by Statista, there has been a progressive increase from 990 thousand metric tons in 2016 to 1.4 million metric tons in 2022.

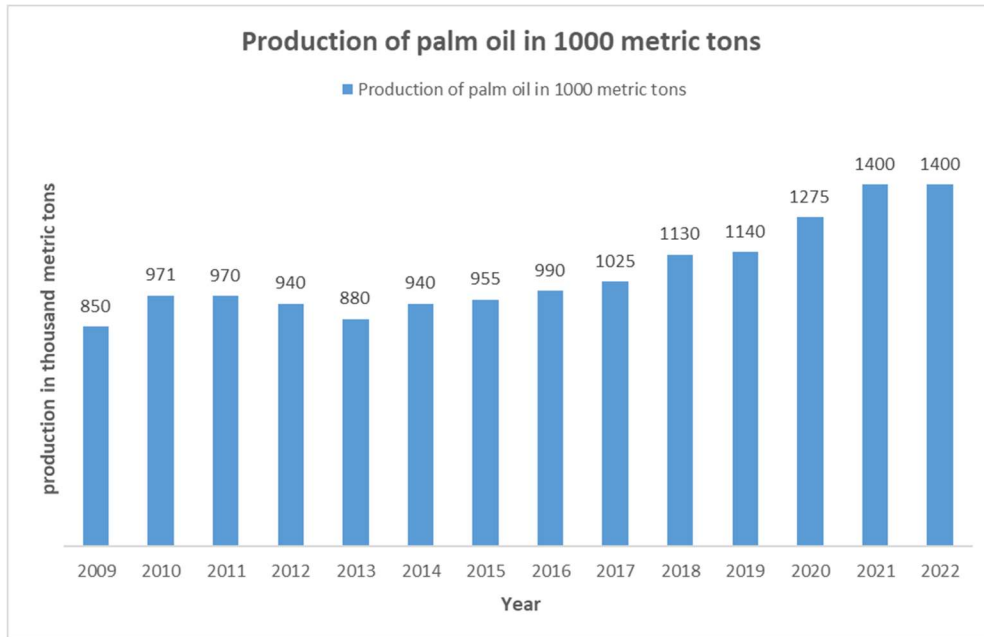


Figure 1: Production of palm oil in Nigeria from 2009 to 2022

Source: (Statista, 2022)

Between 2021 and 2022, a growth rate of almost 10 percent was observed. Percentage change in volume of palm oil production between the year 2010 to 2013 decrease drastically with a percentage decrease from 14.24 percent to -6.38 percent as shown in figure 2. This negative downward trend in production could be associated with climate change which hinders sustainability of crop cultivation. This climatic change can be in form of changes in temperature, rainfall, flood, drought, pest and disease infestation. Others could be as a result of deforestation, urbanization, market dynamics etc.

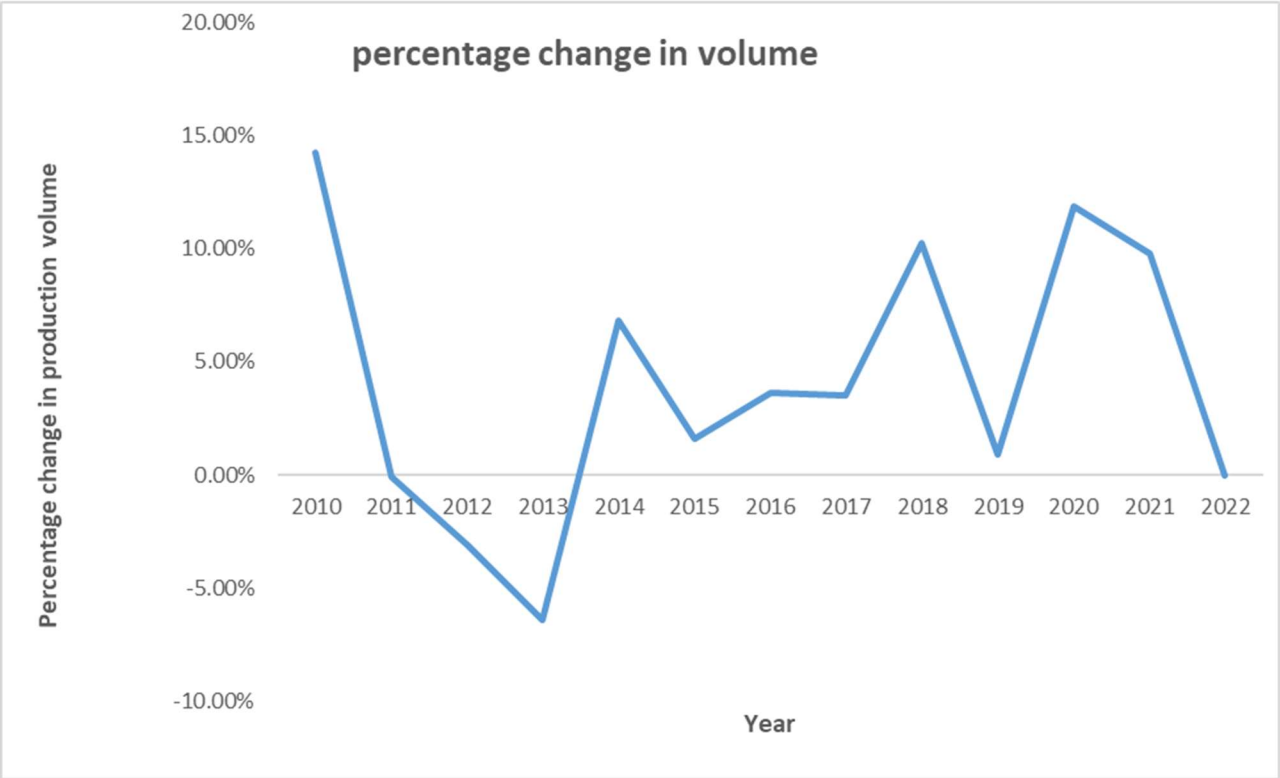


Figure 2: Percentage change in production volume of palm oil from 2010 to 2022.

Source: (Statista, 2022)

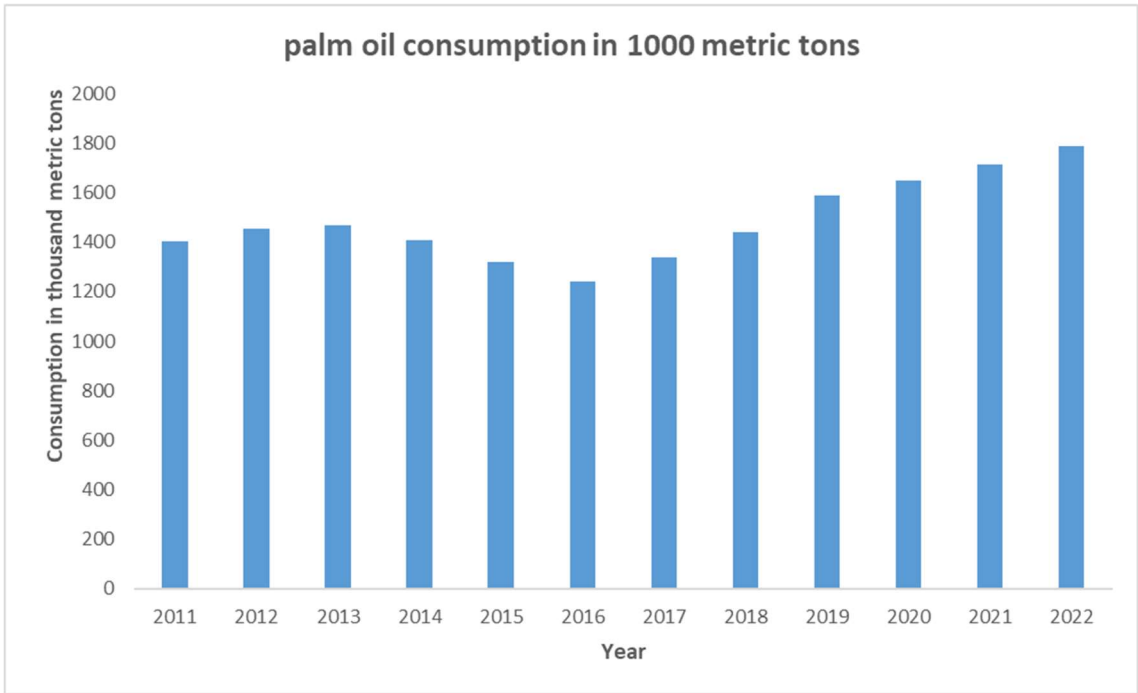


Figure 3: Palm oil consumption in Nigeria from 2011 to 2022 (in metric tons)

Source: (Statista, 2022)

Nigeria expectancy rate of consumption is around 1.8 million metric tons as of the year 2021 to 2022 from figure 3 above. Palm oil to the tons of 350 thousand metric tons were imported in the year 2018 compared to the previous 10 years (Statista 2022).

2.2 Benefits of palm oil industry in Nigeria

The palm oil industry has the potential to generate significant economic and social development in Nigeria. Palm oil is one of the most important economic agricultural products in the country. It provides a means of income and economic development to most of the rural community in the Niger Delta region of the country. There is rapid growth in recent decades in the global palm oil market with current production estimated at 45 million tons. In Nigeria, palm oil industry is one of the economic boosters, as it has helped tremendously in alleviating poverty in the rural community. An efficient and strong palm oil sector in Nigeria will enable the poor to be part of the solution to poverty challenge through provision of employment and a means of livelihood. (Gharleghi & Yin Fah, 2013)

2.3 Palm oil market in Nigeria

Nigeria was a major player in the global oil market between 1950 to 1960. The then production of oil palm in Nigeria surpass the consumption. This trend soon became history since the discovery of crude petroleum oil and total dependency on local processing technique. Negligence in oil palm continuation was encountered as a result of the civil war which lasted between 1967-1970 (PIND, 2011).

Consequently, Nigeria lost her leading role globally to Indonesia and Malaysia in oil palm production. Presently, Nigeria struggles to meet its domestic demand of oil palm because of huge local supply gap and reliance on importation of oil from other neighboring West Africa countries. These present trend is due to population increase of over 200 million people and income growth in relation to low production in the country's oil palm industrial sector (Tiku & Bullem, 2015). Local production cannot match up with the ever increasing population. This short coming is presently augmented via importation

from neighbouring West Africa countries (IPPA, 2010). According to (Statista, 2022) import value of crude palm oil in Nigeria in 2022, crude palm oil worth 43.4 million U.S dollar was imported in the third quarter of 2002 from Malaysia while Singapore played a significant role in the previous quarter.

There are three main oil product of palm oil namely; Technical Palm Oil (TPO), Special Palm oil (SPO) and Palm Kernel Oil (PKO). Other significant products are Palm Kernel Cake (PKC), sludge, palm wine, wood product (PIND, 2011).

The value of palm oil in the international market trade are determine by the amount of free fatty acid (FFA), dirt, and iodine value. SPO has FFA content of less than 5 percent which makes it suitable for consumption and body usage. On the other hand, TPO has FFA greater than 5 percent and is principally used for cooking domestically (PIND, 2011).

Palm oil market in Nigeria trade centers majorly on low quality TPO which is directly sold as unprocessed oil, high quality refined SPO used in food processing industry and PKO which has gained recognition presently in the industrial market. Most household preferred TPO for consumption because of the higher FFA characterized with tangy flavour. There is increased in demand of TPO in Nigeria market today due to population increase in the country. On the contrary, SPO traders has opined that supply of the product is insignificant as a result of the local miller's inability to meet the industrial standards of delivery. TPO, SPO and PKO supply to consumers is carried out by both local and foreign sources. The local sources are palm oil dealers, secondary processors and automated processing plant owners. Three main group of consumers of the oil palm are house hold consumers of the TPO, commercial users of the TPO and industrial users of SPO and PKO. The major buyer of SPO/PKO products in Nigeria are Sunny Oil Nigeria Limited, Planet Oil and Chemical Industry Limited, Phemson Nigeria Limited, Emily Millionaire Cosmetics, OM Oil Industry Limited, PS Mandrides etc (Tiku & Bullem, 2015, PIND, 2011)

2.4 Palm oil extraction processes.

Oil palm fruit consist of the outer layer called exocarp, a middle layer called the mesocarp and the inner layer which is the kernel or seed. Palm oil is obtained from the middle layer mesocarp of the oil palm fruit which weighs between 8 to 20 gram per single fruit and 10 to 30 kilogram per FFB (Sundram, et al.,2003). Two type of oil are obtained from the oil palm fruit; the palm oil obtained from the soft middle layer mesocarp and the palm kernel oil obtained from the hard inner layer kernel or seed (Taiwo et al., 2000).

The oil palm fruit pass through several steps to produce the palm oil. These processes are mainly sterilisation, bunch stripping or threshing, digestion of the fruit, extraction of the oil, clarification and purification as shown in the figure 4 below.

Most local processors operating on small scale threshed their bunches before it is cooked because of lack of the capacity to generate steam for sterilisation. Their threshed fruit is cooked in water which result to absorption of water by the fruit (Orji & Mbata, 2008).

Sterilisation uses pressurized steam to destroy oil splitting enzymes in order to arrest hydrolysis and autoxidation. In large scale processors, the heat from the steam at about 140 degree Celcius for a period of 75 to 90 minutes weakens the fruit stem making it effortless to remove the fruit from the bunch and also to coagulate the protein, making the oil bearing cells to come together. The main objectives of sterilisation is to deactivate the hydrolytic enzyme responsible to break the oil cells to free fatty acid. The weaking of the pulp structure makes way for the digestion process (Abbas , et al., 2006, Orji & Mbata, 2008).

Digestion process removes the palm oil from the fruit by breaking down the oil bearing cells. The fruit is pounded by rotating beater arms of a rotating shaft in the steam heated cylindrical vessel. The pounding which is done in high temperature destroys the outer layer of the fruit and reduce the viscosity of the oil which lead to complete disruption of the oil cells started in the sterilisation process. This process is not cost effective for small scale processor due to absence of heat insulation and steam injection that maintain and sustain the temperature in the course of the process. The risk of iron

contamination of the palm oil is highest in the digester due to the wearing of the metal in the process of milling (Owolarafe, et al., 2002, Orji and Mbata 2008).

Oil extraction is done with two methods namely; the dry method which make use of the mechanical presses and the wet method which uses hot water to extract the oil. The dry method could either be batch operation that operates small amount of the raw material or continuous operations that operates large amount. The objective of either operation is to get or squeeze the oil out of the combination of the fibre, oil moisture, and nuts through subjection to mechanical pressure. Metal contamination is also possible here because of the wear during the pressing process (Owolarafe & Faborode, 2008, Owolarafe et al., 2002).

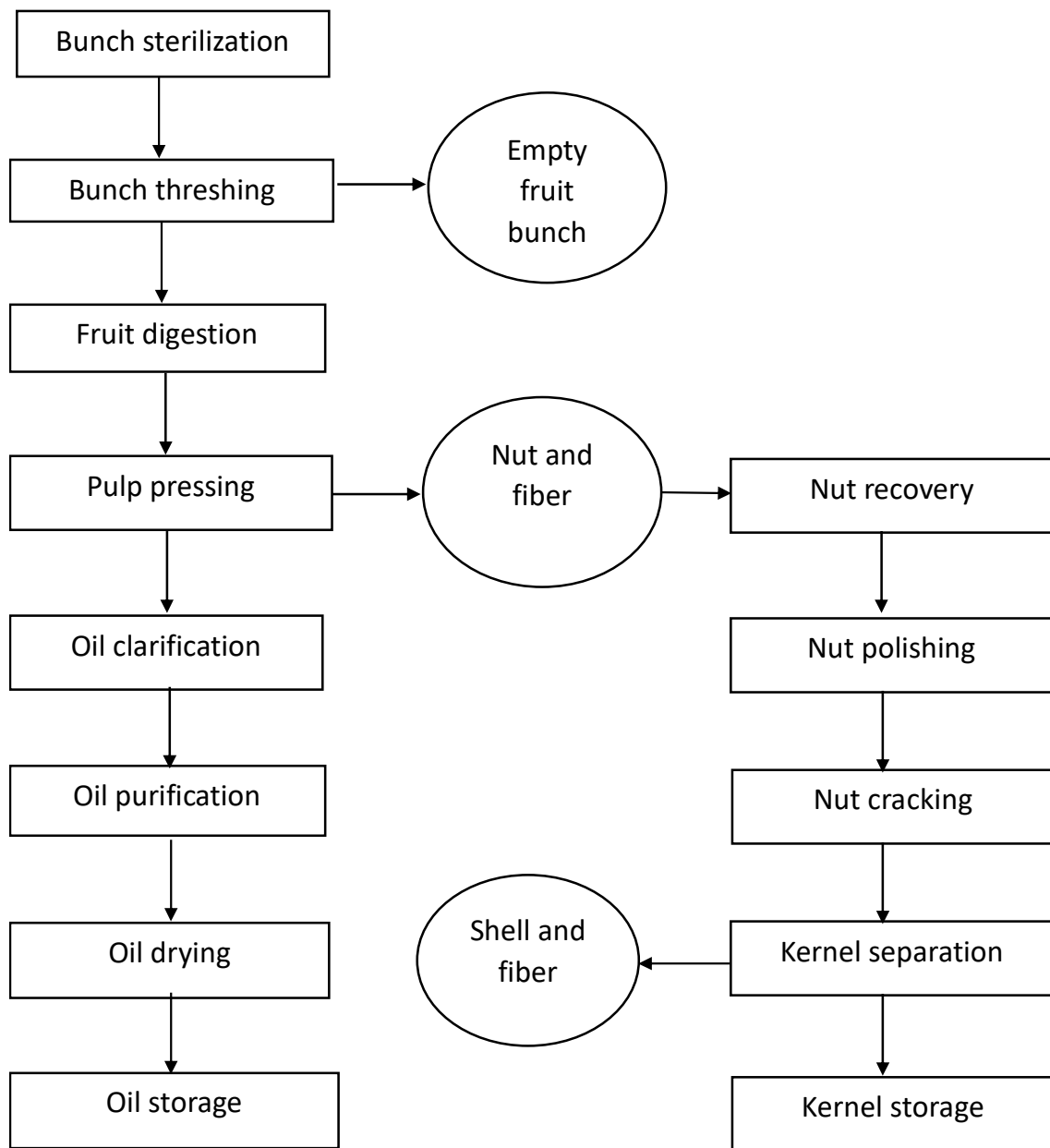


Figure 4: Flow diagram of conventional palm oil unit operation.

Source: (Mustapa et al., 2009)

The purification of the extracted oil starts with the clarification process which removes the estrained impurities. Here, hot water is supplied to the pressed viscous products (oil, fibre nuts). The aim of adding the water is to dilute the mixture from the press and decant the oil to the top of the liquid portion, while the solid components go down the buttom of the container. Water addition is in ratio 3:1. The clarified oil decanted contain some amount of water and dirts. To remove these unwanted materials fro the oil, the decanted oil is reheated in a pot and skimmed carefully in order to drain out the impurity and water moisture from the oil. The purified dried oil is stored in a storage tank lined with a protecting coating to avoid iron contaminatio. To prevent solidification of the oil, the stored oil temperature is maintained using how water or low pressure heating steam coil at 50 degree Celsius (Taiwo, et al., 2000, Owolorafe et al., 2002).

The nut and fibre mixture residue from the press are separated manually by hand in small scale operations. The nut are further dried and sold to palm kernel oil operators that process the kernel into palm kernel oil (PKO). In large scale mill, the nut shell and fibre are use as source of heating the steam boilers. The high temperature heated steam drives the turbine that generate electricity for large scale mill processor. To recover the kernel in large scale, depericarer is used to separate the fiber from the nuts. The nuts are further dried and cracked in centrifugal crackers to release the kernels. Hydrocyclone seperation using hot steam is used to remove the shells from the kernel (Owolorafe, et al., 2002,Owolorafe & Faborode, 2008).

Palm oil obtained via oil palm processes is crude and red in colour due to the carotenoids pigment found in the plant. Two main content for measuring the standard of palm oil are the free fatty acid (FFA) value which has a balance ratio of saturated and unsaturated FFA and the iodine value. Roundtable Sustainable Palm Oil (RSPO) standard for crude palm oil is to have FFA content of less than 5 percent, moisture content of less than 0.1 percent and not more than 0.01 percent dirt. (Sundram et al., 2003).

2.5 Palm oil extraction method

Extraction of palm oil from the oil palm fruit begins with the cutting of the ripe FFB from the oil palm plantation or farm, followed by sterilisation process in the factory (Orji & Mbata, 2008).

Palm oil extraction is done mainly with three methods. These are small scale, medium, and large scale methods. The method engaged is dependent on the capacity of the processing industry. High quality yield of the oil is mainly from the large scale processing methods (Taiwo, et al., 2000, Orji & Mbata, 2008). This method is capital intensive and involve the use of mechanised system all through the process of extraction from the sterilisation to the clarification (Owolarofe, et al., 2002). In semi mechanised methods, some processes are mechanised while others are unmechanised. Most industry use semi mechanised method in processing the palm oil and mechanised the digestion stage (Orji & Mbata, 2008). The small scale extraction have the poorest quality palm oil. In West Africa, 23 percent of the FFB processes is done with the mechanised process and 77 percent is done using the small scale processing methods (Taiwo, et al., 2000).

Most small scale operators in Nigeria make use of the hand spindle press, digester screw press and the hydraulic press. While the oil palm recovered from the hydraulic press is between 70 to 90 percent, that obtained from the hand spindle is between 60 to 80 percent. (Owolarafe & Faborode, 2008). These press system requires large amount of energy and time consuming when compared to the mechanised system eventhough it cost effective (Owolarafe, et., 2002).

2.6 Characteristics of palm oil

Palm oil colour varies from light yellow to orange red depending on the species and the processes involved. the oil has high palmitic acid, β -carotene and vitamin E content. The magnitude of the colour depends on the carotenoids content of the oil which is reason for the high vitamin A content in the oil. When bleached and refined, the carotene is eliminated resulting in the disappearance of the crude colour (Hadi, et al., 2009).

Palm oil is highly rich in glycerides made up of fatty acids. The major constituents of glycerides in palm oil is triglycerols and FFA. The FFA from chemical analysis shows that it contains 50 percent saturated and 40 percent mono unsaturated and 10 percent poly unsaturated fatty acids (Sundram, et al., 2003). Other contents of palm oil when it is in crude state include carotenoids, vitamin E (Tocopherol), tocotrienols, sterols, phospholipids, glycolipids, aliphatic hydrocarbon and other trace impurities (Sundram, et al., 2003).

Table 3: Physicochemical properties of palm oil.

Characteristics	Range
Apparent density at 50 0C (g/ml)	0.892-0.899
Melting point (0C)	33.0-45.0
Refractive index at 50 0C	1.449-1.456
Solidification point (0C)	35.0-42.0
Specific gravity at (50 0C)	0.888-0.889
Viscosity (cP)	45.0-49.0
Iodine value (g/100g)	46.0-56.0
FFA (% FFA as palmitic)	3.17-5.0
Saturated fatty acid SFA (%)	49.9-54.7
Mono-unsaturated fatty acid MUFA (%)	37.1-39.2
Poly-unsaturated fatty acid PUFA	8.1-10.5

Source: (Mba et al., 2015)

Table 4: Fatty acids composition of palm oil

Acid name	Acid atomic chain	% mean
Lauric	C 12:0	0.2
Myristic	C 14:0	1.1
Palmitic	C 16:0	44.0
Stearic	C 18:0	4.5
Oleic	C 18:1	39.2
Linoleic	C 18:2	10.1
others	others	0.9

Source: (Njoku et al., 2010)

2.7 Uses of palm oil

Palm oil is used mainly as cooking oil found in almost every household. Non food products such as margarine, tooth paste, soap, detergent, candles, cosmetics, ice cream can be prepared from palm oil either as main ingredient or one of the ingredient (Njoku, et al., 2010).

Palm oil is used for medicinal purpose as antidotes to neutralize poisons taken to the body system. Studies has shown that palm oil can be used to blend fuel used in internal combustion engine (Njoku, et al., 2010).

Table 5: Food and non-food uses of palm oil

Food uses	Non-food uses
Cooking oil	Cosmetic and personal care
Deep Frying Oils	Soaps
Margarines and spreads	Candles
Bakery fats	Pharmaceuticals
Cocoa butter alternatives fats	Lubrication and Grease
Confectionary fats	Surfactants
Ice cream fats	Industrial Chemicals
Infant nutrition fats	Agrochemical
Other food application	Coatings
	Paint and Lacquers
	Electronics
	Leather
	Biodiesel

Source: (PIND, 2011)

Chapter 3

3 Oil palm waste products and utilization

The process of palm oil production generates different forms of waste at each processing phase. Waste from the palm oil industry are generated from both the plantation activities and the milling process. Solid waste generated from the plantation activities are trunks, fronds and the leaves. On the other hand, solid waste generated from the mill are the empty fruit bunch (EFB), palm kernel cake (PKC), decanter cake, fibre and shells. PKC is the left over from the oil extracted from the palm kernel seeds. (Embrandiri et al., 2013).

Study from Chavaparit et al 2006 in Thailand reported that for every ton of FFB processed, 140kg of fibre, 60kg of shells, 240kg of EFB and 42kg of decanter cake is generated (Embrandiri et al., 2013).

Table 6: Oil palm waste products and uses

No	Type of palm waste residue	Uses
1	Palm press fiber (PPF)	Was used as source of fuel for the mill. Used as stock for animal feed when mixed with soybean and fish meal. Used as potting material for ornamental plants to improve the growth of foliar. Used for making fibre boards Polymeric composites for building materials referred to as agrolumber for product like wall panel, sub-floors, doors, and furniture parts.
2	Decanter cake (DC)	Used as livestock for animal feed. It can be combined with inorganic fertilizers to enrich soil quality on palm plantations
3	Palm kernel cake (PKC)	It has 48% carbohydrate and 19% protein which make it suitable as feedstock
4	Palm kernel shells (PKS)	Used majorly for fuel. Converted into activated carbon for water purification purposes
5	FronDs, trunks and leaves	Used as mulching material in the fields which helps in moisture retention. Also used as roofing material and some are processed as furniture.
6	Empty fruit bunch (EFB)	Generating steam for the mills and ash residues used as fertilizer. As raw material for products such as paneling, composites, fine chemicals, pulp and paper as well as compost and bio-fertilizer. Main substrate for the cultivation of <i>Pleurotus ostreatus</i> (oyster mushroom)
7	Palm oil mill effluent (POME)	Mainly used for ferti-Irrigation purposes but due to its acidic nature is quite toxic to flora and hence needs to be treated. Carotenes are extracted from POME by pharmaceutical industries.

Source: (Embrandiri et al., 2015)

3.1 Palm oil mill effluent

Effluent water is defined as the water discharge from the industry after usage in processing. This water can be toxic and harmful to the environment if left untreated. The toxic nature of most effluent water is due to the soluble material content such as methane, sulfur dioxide, ammonia, halogens and soluble liquids or solids which contain ions (Igwe & Onyegbado, 2007).

To reduce the toxicity of effluent to the environment, effluents are treated before discharge to the environment. The major aim of treatment of effluent is to reduce the amount of these toxic compounds to acceptable threshold limit value of the standard of World Health Organization (WHO), Federal Environmental Protection Agency (FEPA) (Igwe & Onyegbado, 2007).

Characteristics of most effluent from industrial processes are the presence of organic suspended solids that depletes dissolved oxygen, inert suspended solids causing turbidity, toxic substance and heavy metals, oil and floating materials, dissolved salts especially phosphate and chlorides (Igwe & Onyegbado, 2007).

Large amount of waste is produced in the palm oil mill industry during the oil palm processing. The process of extracting the oil results in by product commonly referred to as palm oil mill effluent (POME). POME is made up of dissolve constituent such as high concentration of protein, carbohydrate, nitrogenous compounds, lipids and minerals which are converted to useful materials such as methane and carbon dioxide with the aid of microorganisms. The quality of the raw oil palm fruit determines the characteristics observed in the effluent (Rupani et al., 2010). In palm oil production, 5-7.5 tons of water is required for producing 1 ton of crude palm oil. More than 50 percent of the water ends up as palm oil mill effluent POME. (Ohimain & Izah, 2014). POME contains 95 percent of water, solids; 2 percent suspended solid, and 2 percent dissolved solid, and 1 percent of residual oil. POME, if untreated is harmful to the environment depleting dissolved oxygen in aquatic environment and waterlogging the soil and killing vegetation. In the processing of oil palm fruits, POME is generated from fruit washing, sterilization of the FFB, clarification of the crude palm oil, hydro-cyclone separation of the kernel with hot steam and blowing down of boilers, tank and decanter drain (Rupani et al., 2010).

3.2 Characteristics of POME

Raw POME is a brownish colloidal suspension containing high concentration of organic matter. It is usually hot when coming from the mill. It is low in pH because of the organic acids produced in the fermentation process, usually 4-5. Large amount of total solid is contained in POME (40,500mg/l oil, grease 4000mg/l, chemical oxygen demand COD 50,000mg/l and biological oxygen demand BOD 25,000mg/l), as shown in table 7 below. POME contain useful amount of Nitrogen, phosphorus, potassium, and calcium. These are vital ingredient for fertilizer industry use for plant growth (Rupani et al., 2010).

Table 7: Characteristics of raw POME and the regulatory discharge limit

Parameters	Value	Regulatory discharge limits
Temperature ° C	80-90	45
pH	4.7	5-9
Biochemical oxygen demand BOD 3 days at 30 ⁰ C (mg/l)	25000	100(50)
Chemical oxygen demand COD (mg/l)	50,000	-
Total solids T.S (mg/l)	40,500	-
Total suspended solids T.S.S (mg/l)	18,000	400
Total volatile solids T.V.S(mg/l)	34,000	-
Oil and Grease (mg/l)	4000	50
Ammonia Nitrate (mg/l)	35	150

Source: (Rupani et al. 2010)

Table 8 presents heavy metal content of POME treated with anaerobically digestion method via a covered lagoon. Essential metals such as copper, manganese and zinc have higher content than the non-essential metal such as cadmium and lead.

Table 8: Heavy metal content of POME from anaerobic sludge and treated POME sludge.

Heavy metal	Treated POME sludge (mg/kg)	POME Anaerobic sludge (mg/kg)
Copper	45.05 + 2.87	70.40 + 21.60
Chromium	27.86 + 0.55	9.30 + 0.20
Cadmium	0.41 + 0.01	nd
Zinc	130.11 + 3.49	151 + 14.50
Lead	0.38 + 0.10	0.5 + 0.60
Nickel	10.77 + 0.15	14.0 + 2.2
Manganese	422.56 + 12.04	495.24 + 48.3

Source: (Khairuddin et al., 2016; Baharuddin, et al., 2010)

3.3 Palm oil mill effluent management

Palm oil mill effluent discharged into the environment without treatment results in clogging and water logging of the soil and kills the vegetation on contact. This effluent discharge results to death of aquatic organisms and depletion of dissolved oxygen. POME can be turned from harmful waste to useful sustainable fertilizer for irrigation of agricultural soil (Rana et al., 2017). Primarily, mechanical, and biological techniques are combined in the treatment of POME. Mechanical method or technique is usually the first stage in treatment of most effluent. This method reduces or removes the total suspended solids particles otherwise called primary treatment. This method can be sedimentation, filtration, ultra-sonication, decolorization, and dissolved air flotation. The biological

technique reduces the organic load rate in the effluents via biological degradation of the effluent in a bioreactor or bio-digester (Salihu, 2012)

POME can be treated via several ways such as conventional treatment systems like the pond system which include aerobic or anaerobic or facultative open digestion tanks and advanced technology based bioreactor. These methods are well known to be efficient in treatment of POME. Ponding system is prominent and most common method used in the treatment of POME in palm oil mills followed by open digester tank. The processing capacity of the palm oil mill and the volume of effluent generated determine the ponding system to be engaged. Ponding system has low cost of maintenance, cost-effective, reliable, efficient with simplicity in design. However, the ponding system is land and time intensive as it requires extensive land area. It is also disadvantaged in having long hydraulic retention time (HRT) of about 100 to 160 days before discharge. Moreover, large amount of methane gas which accounts for 70 percent of the total greenhouse gas emission is released into the atmosphere due to the decomposition in the anaerobic pond phase (Poh & Chong, 2009).

In this system of treatment, POME flows through a series of pond with several steps of treatment. The pond in one mill may differ from another mill. Four types of pond make up the open ponding system namely; a fat pit, cooling pond, anaerobic pond, and aerobic pond. The remaining oil in the effluent after extraction from the mill is recovered in the fat pit and returned to the main crude palm oil product. The cooling pond reduces the POME temperature from the mill to about 35-38 degree Celsius, buffer the pH and optimize the conditions for the decomposition of the organic materials in the anaerobic and aerobic pond. After treatment in these four ponds, the effluent is safe to discharge or use as fertilizers in the farm or plantation (Poh & Chong, 2009).

3.3.1 Anaerobic digestion treatment process

This treatment method degrades organic waste in an anaerobic digester with the aid of anaerobic micro-organisms which produce methane, carbon dioxide and sludge as end product. Different type of microorganism converts complex organic compound into

simple one. Anaerobic treatment method has proven to be effective and efficient over the years in treatment of highly organic BOD and COD effluent.

Anaerobic digestion take place over four stages as shown in figure 5. The digestion process begins with the hydrolysis process where insoluble long chain polymers of fats, carbohydrates and protein are broken down into short chain polymer through bacteria hydrolysis. In this first phase, extended string organic polymers such as polysaccharides, lipids and proteins are hydrolyzed to soluble shorter chain polymers such as sugar, fatty acid and amino acids. Enzymes produce by microorganisms such as cellulose, amylase, lipase or protease perform this process (Tamrat et al., 2013; Igwe & Onyegbado, 2007)

Acidogenic bacteria converts fatty acids, amino acid and sugar into carbon dioxide, hydrogen, ammonia and organic acids. In this phase, the amino acid, fatty acid and sugar formed is used as substrates by the anaerobic oxidizers. The acidogenesis phase is a very rapid process where acid bacteria convert the organic component of the waste into volatile fatty acids (VFAs) which the methanogenic bacteria use as substrate (Rana et al., 2017, Rahayu et al., 2015).

In the acetogenesis phase, the acetogenic bacteria converts the organic acid into acetic acid. In this phase, fatty acids and ethanol are converted into acetate by acetogenic bacteria that possess the ability to generate hydrogen and carbon dioxide. Acetogens are environmental sensitive and need long period to adapt to new environment. Lastly, methanogenic bacteria convert this product into gases particularly methane (Rahayu et al., 2015, Igwe and Onyegbado, 2007).

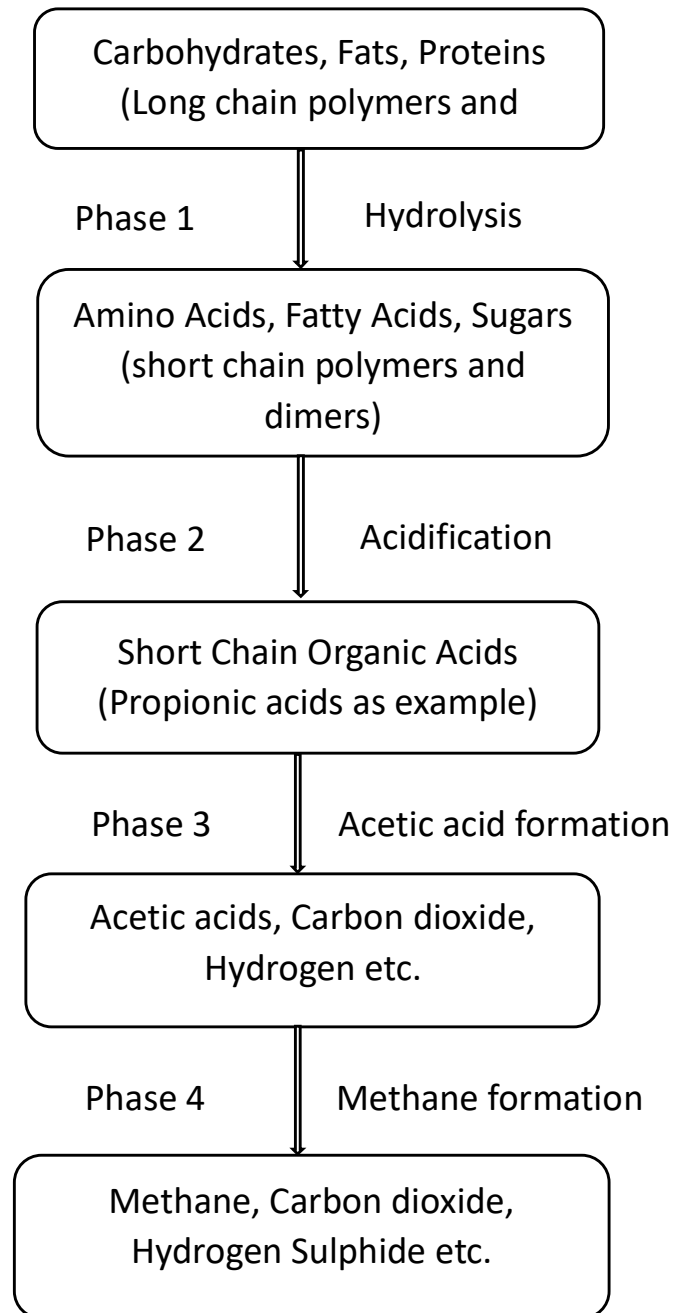


Figure 5: Anaerobic digestion process

Source: (Rahayu et al., 2015)

3.3.2 Ideal conditions for anaerobic digestion

For efficient and effective treatment of organic material such as POME in anaerobic digestion condition, specific nutrients and environmental condition are needed. These include:

Nutrient such as macro nutrient (carbon, hydrogen, oxygen, nitrogen, sulphur, phosphorus, potassium, calcium, magnesium) which are source of food for bacteria and micro nutrient (iron, nickel, zinc, manganese, molybdenum, and cobalt) which are source of medicine to keep the bacteria healthy. Nutrient help build the cells of the micro organism (Rahayu et al., 2015).

Temperature required for the efficient treatment in digester can be either in mesophilic range (25 to 40 degree Celsius) or thermophilic range (50 to 60 degree Celsius). Anaerobic digestion treatment plant usually prefer the mesophilic range because temperature control system are required in the thermophilic (Rahayu et al., 2015).

pH around 7 is required for optimum growth and activity of the bacteria. Recent studies have proven that pH range of 6.5-7.5 is good and ideal for anaerobic digestion systems (Rana et al., 2017)

3.3.3 Comparison of anaerobic and aerobic digestion

While both aerobic and anaerobic digestion effectively lead to degradation of organic materials, aerobic process occur in the presence of oxygen and anaerobic process occur in the absence of oxygen. Most palm oil mill owners prefer the anaerobic process because of its high yield of biogas which is captured and used to power the boilers and for onsite consumption. Moreover the treated effluent which is rich in nitrogen, phosphorus and potassium is used for irrigation of agricultural farmland or plantation especially oil palm plantation.

Table 9: Comparison of aerobic and anaerobic digestion

Aerobic	Anaerobic
Aeration	No aeration
High energy cost	Low energy cost
Completely treated water	Pre treated water
High surplus sludge (30-60%)	Low surplus sludge (5-10%)
Heat loss	Energy from biogas

Source: (Rahayu et al., 2015)

3.3.4 Anaerobic digestion technology

There are several anaerobic digestion technologies for industrial effluent treatment. Palm oil mill operators can choose among any of these technologies depending on the volume of effluent generated and financial capacity. The aim of all the design is to guarantee adequate interaction between the substrate and the micro organism and secondly to prevent the washing out of the microbes from the systems. (Rana et al., 2017).

Six most common technologies for the anaerobic digestion are continuous stirred tank reactor (CSTR), covered lagoon, Anaerobic filters, fluidized and expanded beds, upflow anaerobic sludge blanket (UASB) and expanded granular sludge bed (EGSB) (Rana et al., 2017).

POME is highly organic with high solid content both suspended and dissolved. POME is highly selective of the technology usage in digestion process. For example, it is a hard task to treat POME with anaerobic filters, fluidized bed, UASBs, or EGSB,. These systems require mechanical pre-treatment of the POME to remove the solids and oil making these technologies less efficient (Rahayu et al., 2015).

Large palm oil mill operators or owners mostly use CSTR or covered lagoon for POME treatment. These two technologies are advantageous in handling effluent with high solids such as POME, simple to maintain and operate and affordable compare to others. (Rahayu et al., 2015)

3.4 Palm oil mill sludge (POMS) characteristics

Palm oil mill effluent contains abundant quantities of solids, both suspended solids and total dissolve solids. These solids are commonly named palm oil mill sludge POMS. While the suspended solid is in range of 18,000mg/l, the dissolve solid is 40,000mg/l. POMS effects on the environment is detrimental and as a result, proper technology is needed for mitigating this effect. The sludge can be dried in pond and used as fertilizer because of its high nutrient availability (Rupani et al. 2010)

Table 10: Physicochemical analysis of raw POMS and empty fruit bunch

Parameters	POMS (average)	Empty fruit bunch
Moisture content %	85.0	60
pH	8.4	6.7 ± 0.2
Organic matter	60.0	-
Total organic carbon TOC	33.0	-
Total Nitrogen TN	3.6	58.9 (%)
Phosphorus as P ₂ O ₅	0.9	0.6 ± 0.1 %
Potassium as k ₂ O	2.1	2.4 ± 0.4 %

Source: (Rupani et al. 2010)

3.5 Palm oil mill sludge management

Palm oil mill sludge is generated from POME treatment. This sludge when untreated can be detrimental to the environment causing harm. POMS is often treated with the open ponding system but limited to use during the raining season due to possibility of overflowing of the sludge and longer time needed for drying the sludge. Composting and vermicomposting technology are some of the effective ways of sustainable management of the palm oil mill sludge.

Composting process involves decomposing the substrate by aerobic microorganism and this breakdown the biodegradable organic compounds constituent while the remaining portion is converted into humic acids like substances. Composting help reduce

the volume/weight of sludge. This is done by first dewatering and draining excess water from the sludge in order to attain a suitable moisture level. Some of the processes involved in composting are the addition of biodegradable bulking waste such as shredded yard waste, rice husk, saw dust or other carbon rich materials that help create air pocket which prevents the sludge from compacting and also balances the carbon to nitrogen (C/N) ratio. This adjustment of the (C/N) ratio helps to achieve optimum ratio of composting. Composting is a viable approach for the transformation of POMS into compost, which serves as valuable fertilizers for plantation applications. It is an effective solution for the conversion of POMS into nutrient rich compost (Rupani et al., 2010).

Vermicomposting on the other hand involves the transformation of biodegradable waste into premium is effortlessly accomplished through the help of specialized earthworms such as *Eisenia fetida*. The earthworm which have insatiable appetite for organic matter, break down the organic matter rich sludge into a nutrient rich humus like vermicast. The vermicast with low level of contaminant hold more nutrients because of its homogenous nature. The other useful product obtained from the vermicomposting process is the earthworm biomass which can be further process as animal feed due to its rich protein content. This process is efficient, sustainable, cost effective and environmental friendly (Rupani et al., 2010).

Chapter 4

4 Heavy metals and Nigeria soils

Heavy metal studies have been prominent in the last four decades due to its significant effect on the environment. The definition of heavy metals is usually based on the atomic density property. Most studies have defined heavy metal as metallic element with atomic density five times the density of water. Apart from the definition of heavy metals based on the atomic density by most studies, one crucial definition of heavy metal is that it forms positive ions in solution (Appenroth, 2010). Arsenic, Cadmium, Chromium, copper, Mercury Lead, Zinc are some of the heavy metals that majorly exist in the environment (Bakshi et al., 2018).

With adverse effects to the environment and humans, heavy metal is often referred to as trace elements because with its very low concentration in soil, plant and living organism, it is detrimental. Other studies opined that toxic element or micro element is a suitable name for this metal. Regardless of opinions, heavy metals are toxic above required concentration. They can degrade soil quality, contaminate ground water when leached, pollute food chain stages and cause harm to man (Wuana & Okieimen, 2011, Bakshi et al., 2018). Regulatory limit of heavy metals (mg/kg or ppm) in soils of some countries are shown in table 10 below.

**Table 11: Regulatory limit of some selected heavy metal in agricultural soil
(mg/kg)**

Country	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Australia	20	3	50	100	1	60	300	200
Canada	20	3	250	150	0.8	100	200	500
China	20-40	0.3-0.6	150-300	50-200	0.3-1.0	40-60	80	200-300
Germany	50	5	500	200	5	200	1000	600
Tanzania	1	1	100	200	2	100	200	150
Netherlands	76	13	180	190	36	100	530	720
N. Zealand	17	3	290	>100000	200	N/A	160	N/A
UK	43	1.8	N/A	N/A	26	230	N/A	N/A
USA	0.11	0.48	11	270	1	72	200	1100
NGA(FEPA)	N/A	N/A	N/A	70-80	N/A	N/A	1.6	300-400

Source: (Bakshi et al., 2018)

On the contrary, heavy metal in right concentration can be important to the health and ecosystem. Many metallic elements are essential in function for living organisms. These metals constitute nutritional requirement and fulfil physiological role. But constant low subjection to these metals can lead to severe environmental and health issues. On the other hand, above required concentration, these metals can be poisonous with deteriorating effects to its victim. Heavy metals poisons to human come especially from food and water link in the food chain that support animal life. These metals apart from ingestion get into human system through inhalation, direct contact via the skin as well as

indirect contact. Heavy metal from airborne sources can be inhaled by workers in such airborne heavy metal contaminated environment. Long term inhalation of these metal can be detrimental on the inhaler (Wuana & Okieimen, 2011).

Heavy metal accumulation property makes the metal get concentrated as they progress through the food chain. The low solubility of most heavy metal in water makes it to accumulate in soil. Other unique property of heavy metal is that it is non-biodegradable like other organic compound. It is persistent in the environment due to its good chemical stability. Its high melting and boiling point makes it suitable for industrial use in alloys and as construction materials. Most of the heavy metal has good electrical and thermal conductivity hence, use in electrical and electronic industry (Wuana & Okieimen, 2011).

Heavy metals are naturally present in many soils but vary in concentration in this natural form. The metal in the natural soil come from pedogenic processes; that is weathering of soil parent materials to a level that are less toxic. according to studies, heavy metal present in the natural form in soil indicate no contamination. This natural form of heavy metal level in soil often increased in concentration as a result of anthropogenic activities. Soils are often contaminated by accumulation of heavy metal via the emissions from increasing industries such as petrochemical industries, agro and food processing, refineries, mining, paint, coal processing. The emissions and discharge from these industries such as mine tailings, paint, sewage sludge, fertilizers and manures, pesticides etc. tends to increase the heavy metal concentration in the soil which result to soil water and ecosystem malfunction. Activity of soil micro-organism are often affected by these metals and consequently affects the soil fertility (Singh et al., 2018). The impact of heavy metal in soil ecosystem is mostly on the plant as plant growth is retarded as a result of inhibition of the photosynthetic process which consequently have significant effects on animals and humans.

4.1 Anthropogenic source of heavy metal

Heavy metal contamination of soil through anthropogenic sources has been the major sources of heavy metal pollution. Anthropogenic activities such as fertilizer

application, long term application of treated waste water, mining activities near farmland or plantation, use of pesticides are some of the major sources of heavy metal pollution in agricultural soil (Bakshi et al., 2018).

The quest to boost the fertility of the soil via fertilizer application has led to the contamination of most agricultural soils with heavy metals. Plant needs both macro and micro nutrient which are insufficient in most agricultural soil. These nutrients are essential for the healthy growth and productivity. Most farmers tend to supply this additional nutritive requirement of the soil in order to have good harvest. Fertilizers are banked on because of its richness in Nitrogen, phosphorus and potassium and other nutrients, important for plant growth. However, many fertilizers also have adverse effect of contributing toxic element to the soil. This is due to the fact that most raw material for making fertilizers contain some trace amount of heavy metal. The consistent application of this fertilizers can accumulate to the level that is lethal in the soil making it toxic (Sankhla et al., 2016, Smiljanic et al., 2019).

Moreover, most plant and crops are affected by some certain pest which affect the yield of the plant. Chemical approved and certified for the treatment of these pests contain metals such as copper, mercury lead, arsenic and zinc. Application of these pesticides usually increase the heavy metal concentrations. Studies shows that heavy metal concentration of the above listed metals in the farm or plantation soils where most pesticides are engaged are usually above the background level (Wuana & Okieimen, 2011).

Again, manure application to soil such as livestock manure, sewage sludge, compost have adverse effect of heavy metal to the soil on long term usage. Most farmers prefer the additions of these waste to farms due to the cost effectiveness. However, some heavy metals are supplement added to the feed of these animals such as poultry birds, pigs, cattle. Adversely, the excreta of these animals contain these metals in a high concentration. Consequently, consistent use of these manure can accumulate and render the soil contaminated.

Sewage sludge which are product of waste water treatment are often use in irrigation of farm lands by farmers as many farmers are less bordered and concern of the

effect of these sludge as they are to the yield of their crops. Persistent use of this treated water for fertilizers purpose can pose danger to the soil. Moreover, metals in this treated sludge can be leached to the ground water under certain environmental and meteorological condition (McLaren et al., 2005).

In mining industries, excessive mining of metals ore has been found to contaminate the soil with heavy metal. This is due to the direct discharge of the tailings. Also heavy metals from airborne sources like stack emissions are release as particles in gas streams. Volatilization of heavy metals during high temperature processing release metals as particles to the air. Stack emissions dispersion of heavy metal over long distance are aided by natural air current. Fugitive emissions near ground level are distributed over small area in the mining environment (Sankhla et al., 2016, Smiljanic et al., 2019).

Good understanding of heavy metal sources is very vital for effective management of the soils. Table 11 below shows both the natural sources and anthropogenic sources of heavy metals.

Table 12: Heavy metal sources

Natural	Anthropogenic
Weathering of soil parent material	Industrial process
Rock abrasions	Organic and inorganic fertilizers
Forest fire	Waste disposal
Aerosol formation	Combustion of fossil fuel
Particle release by vegetation	Mining
Volcanic eruption	smelting
Biogenic sources	Agriculture and forestry

Source: (Yadar et al., 2021)

4.2 Heavy metal remediation techniques

Heavy metal accumulation and non biodegradable properties makes its effect long lasting to the ecosystem. However, some management technique are used to reduce heavy metal contamination in the environment. The remediation technique applied to heavy metal contaminated soil, varies with the degree of contamination, cost, and site condition.

In some cases, these techniques are combined in order to achieve good and effective remediation (Madhupriya, et al., 2020).

Remediation of heavy metal contaminated soil requires either in-situ or ex-situ technique. In most cases, the in-situ technique which involves bringing in treatment to the soil is more economical than the ex-situ which involves the excavation of the contaminated soil for treatment purpose (Liu et al., 2018). Table 12 shows insitu techniques in soil remediation and some methods used.

Table 13: In-situ techniques for heavy metal remediation

In-situ techniques	Methods
Physical	Surface capping, encapsulation
Electrical	Electrokinetics, vitrification
Chemical	Soil flushing, immobilization
Biological	Phytoremediation, bioremediation

Source: (Liu et al., 2018).

4.2.1 Surface capping

This is a prevention method that involves covering the contaminated soil with impenetrable layer or materials such as concrete, asphalt, clay. These materials aimed to confined the contaminated soil and prevent the migration of the contaminants via rain water movement or wind blowing across the site. Capping prevent vertical movement of rain water through the soil. Capping methods is cost effective and efficient (Liu et al., 2018).

4.2.2 Encapsulation

This physical methods involves the containment or isolation of contaminants within the contaminated site to prevent migration of the contaminant. The aim of the encapsulation method is to immobilized the heavy metal contaminant and minimized their escape into the environment. Materials often used for encapsulation totally depends on

the site condition and the contaminants. Example of encapsulation materials use for heavy metal contaminated soils are cementitious binders, geotextiles, clays. Common technique for applying this materials are spraying, pouring or use of injection (Madhupriya, et al., 2020; Akpoveta, 2020)

4.2.3 Electrokinetics

This method involves application of low voltage direct current electric field through contaminated soil of low permeability in order to mobilize and remove heavy metals. In this method, electrodes are placed into the contaminated soil and the electric field aids the ion migration towards the electrodes. The ions are actually mobilized by the electric current to the electrodes where it is removed. The use of suitable electrolyte such as distilled water organic acids or synthetic chelates determine the contaminat removal efficiency of this method (Chen, et al., 2019; Liu et al., 2018)

4.2.4 Soil flushing

In-situ soil flusshing involves the removal of contaminant from the soil by flushing them out using a suitable flushing agent. The contaminated site is flushed with a solution most suitable and appropriate for the removal of the contaminant. Most suitable agent for flushing is water. Other additives such as surfactants, chelating and oxidizing agent can be combined with water to solubilize the contaminant and remove them from the soil matrix. Flushing agent is usually applied through the soil surface or injection wells. The flushing agent with contaminant is obtained through extracton wells or by drainage. Furthermore, the contaminated effluent is treated to remove or reduce the contaminant before disposal. The contaminant concentration can be tracked by analysing sample. This is done to ascertain the degree of remediation (Ramadan et al., 2018; Liu et al., 2018).

4.2.5 Immobilization

This methods involves treating the contaminated soil to render the metals bioavailability immobile. This methods can either be done by stabilization or solidification process. While stabilization is aimed to immobilized the contaminant within the soil matrix using additives, solidification on the other hand, binds the contaminat with the additives to form a solid mass structure. In both cases, the additives inhibit the

physical and chemical properties of the heavy metal. Cement, lime, fly ash and organic polymer are example of additives used in immobilization processes. Immobilization aims to prevent the heavy metals from migrating to other location where they can be contacted by plant or animals (Madhupriya, et al., 2020).

4.2.6 Phytoremediation

This methods involves the use of some certain plant to remove, stabilize or degrade heavy metal in soil. Phytoremediation can either be phyto-extraction, where plants absorp and accumulate the contaminants into their tissue or phyto-stabilization where some certain plant reduce the mobility and availability of the contaminant in soil or rhizofiltration where plant absorb contaminant from water or soil through their root sytem. The mechanism engaged in phytoremediation is dependent on the level of the site contamination and the accumulation capacity of the contaminant by the plant (Yadar et al., 2021).

4.2.7 Bioremediation

In this method, micro organism such as bacteria and fungi degrades or transform heavy metal in contaminated site. Microorganism metabolized or bind heavy metals converting them into less toxic or immobilized forms. Bioremediation can be effective by enhancement of the microbial activity through provision of nutrient for the microorganism (Yadar et al., 2021; Liu et al., 2018).

Table 14: Ex-situ techniques for heavy metal remediation

Ex-situ	Methods
Physical	Land filling
Chemical	Soil washing, solidification
Thermal	Vitrification

Source: (Liu et al., 2018)

4.2.8 Landfilling

This soil remedy technique or method involves the excavation of contaminated soils from its location and disposed to the landfill. The aim of this ex-situ technique is to prevent the release of heavy metals contaminant to living organism and the environment. Landfilling process involves identifying a suitable location for the landfill with proximity into considerations. The design of the landfill is done with liners and barriers which prevent leaching or migration of the contaminant. Clay or synthesis material are often used as liners when designing the landfill. A covered layer which minimize surface water infiltration, odor control is placed on the top of the landfill. Landfill are usually monitored and maintained to avoid leakages. This technique is often time considered as last resort in disposal of contaminant (Liu et al., 2018).

4.2.9 Soil washing

In this soil remedy technique, the contaminated soil is removed from the parent site and a treatment solution is passed through it to remove the heavy metal from the soil. Three main processes applied in soil washing are water washing the soil, agitations and sieving to separate the contaminated fine soil particles. Surfactants is usually added to the contaminated soil to enhance the removal efficiency of the metals (Madhupriya, et al., 2020).

4.2.10 Solidification

In this ex-situ remediation technique, the contaminated soil is removed from the polluted site and it is mixed with binding agent to form a structure which prevent the mobilization of the metals. Cement, lime, fly ash and organic polymer are example of additives used in solidification process (Wang, et al., 2019; Liu et al., 2018).

4.2.11 Vitrification

Vitrification process converts the contaminated soil into a solid glass like structure by subjecting it to a high temperature of about 1000-1500 degree Celsius. Vitrification technique can be either in-situ or ex-situ with the cost of ex-situ always more than in-situ because of excavation of the contaminated soil and the energy requirement for melting.

Moreover, the soil in ex-situ undergo pre-treatment such as sorting, grinding before the heating process. The pre-treated soil is then subjected to a high temperature in a typical reactor. The melted soil is combined with additives such as silica to aid the formation of the glass like substance. These additives immobilize the heavy metal and other contaminants within the matrix. The molten mixture is further cooled to re-solidify into a stable vitreous mass (Madhupriya, et al., 2020).

Table 15: Industrial source of heavy metal

Heavy metals	Sources
Arsenic	Textiles, smelting, phosphate fertilizers, metal hardening, paints industrial dust, pharmaceuticals, wastewater, pesticides, glass manufacturing, herbicides
Cadmium	Phosphate fertilizers, Mining and metallurgy, fertilizers, electronics, pigment, plastic, and paint, industrial and incineration, dust and fumes, wastewater, pesticides, PVC products, sewage sludge usage, plating
Chromium	Metal plating, electro plating, rubber, mining and metallurgy, photography, industrial dust and fumes, tanning, leather industry, chemical industry, fertilizers, textiles industry, painting, photography industry, cement industry, and dyeing
Lead	Industrial dust and fumes, mining and metallurgy, solid waste combustion and incineration, combustion fossil fuel, solid waste, industrial waste, paints and pigment, explosive ceramics and dish ware, pesticides, lead acid batteries production, some PVC types, fertilizers
Mercury	Mining, smelting and metallurgy, scientific instrument, production of chemicals, industrial dust and fumes, industrial waste water, fossil fuel combustion, solid waste combustion, incineration of municipal waste, fertilizers, pesticides, electrical switches, fluorescent bulbs, mercury arc lamps, production of mercury products like

	thermometer and batteries, explosives, rubber and plastics, cellulose and paper.
Nickel	Mining and metallurgy, electroplating, production of iron and steel, industrial dust, industrial aerosols, incineration of waste, fertilizers, combustion of coal, battery, food processing and chemical processing industries
Zinc	Galvanization, iron plating and steel, mining and metallurgy, electroplating, fertilizers, metal waste
Copper	Plating, rayon, mining and metallurgy, electrical and electronic waste, paint and pigment, pesticides textiles industry, explosives
Manganese	Sewage sludge, municipal waste water discharge, combustion of fossil fuel, emission from alloys, steel and iron production

Source: (Smiljanic et al., 2019, Yadav et al., 2021)

The table 14 above shows the main industrial activities whose effluent contain some heavy metal or point sources of heavy metal that most commonly reach the environment due to human activities.

The major anthropogenic activities that lead to accumulation of heavy metal in agricultural soil are shown in table 15 below

Table 16: Source of heavy metal pollution on agricultural soils

Heavy metal	Source of pollution on agricultural soils
Arsenic	Use of arsenic in herbicides, cattle and sheep dips and insecticides use as desiccant for cotton crop to aid mechanical harvesting
Lead	Pesticides, fertilizers impurities, emission from mining and smelting, combustion of fossil fuel from farm machineries, soil located near lead mines, exhaust gases of combustion engines
Chromium	Wastewater, and sludge from dyeing and tanning industries
Cadmium	Phosphatic fertilizers addition, domestic and sewage sludge, wear of automobile tires, mining and metallurgical activities, emission from mining and smelting processes
Mercury	Mercury based fungicides, sewage sludge, combustion of fossil fuel fall out, industrial processes.
Nickel	Fertilizers, manures, metal refining, smelting, burning of coal, and industrial sewage sludge, emission from mining and smelting operations.
Zinc	Fertilizers, manures, pesticides, mining metal refining, smelting, electroplating, sewage sludge
Copper	Manures, fertilizers, pesticides sewage sludge.
Manganese	Sewage sludge, combustion of fossil fuel.

Source: (Smiljanic et al., 2019, Yadav et al., 2021)

Table 17: Toxic effect of some heavy metal in human health

Heavy metal	Toxic effect
Arsenic	It affects essential cellular processes such as oxidative phosphorylation and ATP synthesis
Cadmium	Carcinogenic, capable of damaging the lungs, it affect the bone, causing it to be fragile, disrupt endocrine system
Chromium	Hair loss, cardiovascular disease
Copper	Damage brain and kidney, elevated levels results in liver cirrhosis and chronic anemia, causes stomach and intestinal irritation
Mercury	Auto immune disease, depression, drowsiness, fatigue, hair loss, insomnia, loss of memory, restlessness, disturbance of vision, tremors, temper outburst, brain damage, lungs and kidney failure
Nickel	Allergic skin disease such as itching, cancer of the lungs, nose, sinuses, throat through continuous inhalation, immunotoxic, neurotoxic, affect fertility and lead to hair loss
Lead	Impaired development in children due to excess exposure, reduced intelligence, short memory, disability in learning and coordination problems, a risk of cardio vascular disease
Zinc	Causes dizziness and fatigue
Manganese	Neurological disorder, can trigger oxidative stress, CNS disorder, anemia, irritability, insomnia, sore throat, memory loss

Source: (Madhupriya, et al., 2020)

4.3 Major soil types in Nigeria and management

Nigeria possesses significant arable land and abundant fresh water resources that, when considered together, offer great potential for agricultural development. The country has approximately 71 million hectares of cultivable land, which is 77 percent of the country total area. This provide a substantial foundation for agricultural activities. In addition, Nigeria benefits from wide range of freshwater sources, including major rivers such as Niger and Benue, as well as lakes such as lake Chad and various other rivers like the Osun, Hadejah and Bonny etc (FAO, 2016).

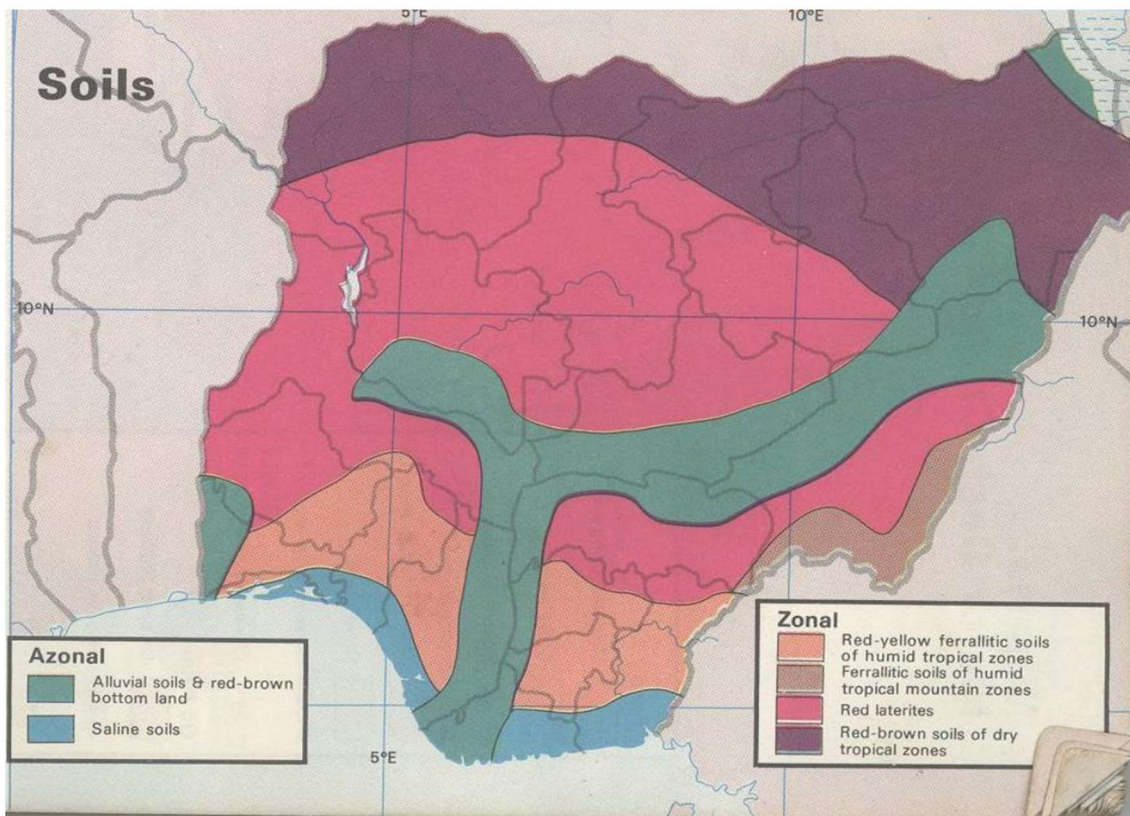


Figure 6: Nigeria soil classification map

Source: (FRN, 2019)

The total renewable water resources in Nigeria amount to around 280 cubic kilometers per year. These water resources, if effectively managed, can play a crucial role in boosting food production and addressing the ongoing food crises in the country. By properly managing soil condition and ensuring sufficient water availability, Nigeria can

enhance agricultural productivity, promote sustainable farming practice and contribute to food security for its timid population (FAO, 2016)

Efforts to improve soil management, including practices like soil conservation, nutrient management and erosion control can enhance soil fertility and productivity. Additionally, efficient water management technique such as irrigation, water storage and water conservation methods can optimize water usage in agriculture especially during the dry season (Ahuchaogu et al., 2022).

By harnessing the agricultural potential land and effectively managing its freshwater resources, Nigeria can take significant strides towards addressing food security challenges, reducing dependency on food imports and promoting self-sufficiency in food production. However, it is crucial to implement comprehensive and sustainable strategies that integrate soil and water management practices, along with appropriate policies and investments, to realize the full potential of Nigeria's agricultural resources (Ahuchaogu et al., 2022).

Soil zones in Nigeria has unique characteristics that influence their agricultural potential. Understanding and managing the soil properties within each zone is essential for sustainable agricultural practices and maximizing crop production in different regions of the country (FRN, 2019).

Nigeria has a diverse range of soils across different ecological conditions, each with varying fertility levels. The soil types in Nigeria are influenced by factor such as climate, vegetation and topography. According to the FAO soil taxonomy, the major soil types in Nigeria include fluvisols, regosols, acrisols, ferrasols, alisols, lixisols, cambisols, luvisols, nitisols, arenosols, and vertisols. These soil types have different agricultural potential (FAO, 2016).

Nigeria soils can be grouped into four zones based on climatic conditions which are also associated with specific soil types as shown in figure 6 above. These group include; northern zone, characterized by sandy soils, interior zone dominated by laterite soil, southern belt, consisting of forest soils and alluvial soil zone found in areas with alluvial

deposits. These soil associations reflect the regional variations in soil characteristics and agricultural suitability within Nigeria (FRN, 2019).

The northern zone of Nigeria is characterized by sandy soils, located in the extreme north and close to the encroaching Sahara Desert. These soils were formed by the deposition of wind-blown sand over long period of time. They are highly suitable for the cultivation of crops such as groundnuts, sorghum, millet and cowpea (FRN, 2019).

The interior zone is composed of laterite soils which are mixture of sand and clay. These soils are typically gray to black, poorly drained, and subject to seasonal flooding, forming what is known as 'fadama'. The soils are deeply weathered, sticky and impermeable to water resulting in low fertility. When the virgin forest on these soils is cleared, their fertility further declines, making them of little agricultural value. However, the Biu plateau within this zone has fertile soil that supports productive agriculture, particularly cotton cultivation (FRN, 2019).

The southern belt is characterized by forest soils, representing the humid, tropical forest climate of the southern region. The soil types in this zone depend on the underlying parent rock, with granite or clay giving rise to rich clayey loam soil. These soils are highly suitable for growing crops such as cocoa, oil palm, and rubber. They play significant role in Nigeria agriculture (FAO, 2016).

The zone of alluvial soil is found along flooded plains, deltas and coastal flats. It extends from the coast inland and follows the valleys of the Niger and Benue rivers, cutting across different vegetational zones. Soils in the zone are freshwater soils with varying compositions, including gray to white sand, gray clay, sandy clay and humic top soil. Additionally, there are saline mangrove soils with a mat of rootlets that have a brownish to black color (FAO, 2016).

4.4 Soil management practices in Nigeria

Nigeria can preserve the productive capacity of its soil, support agricultural livelihoods and contribute to long term food security and environmental sustainability through promoting sustainable soil management practices.

The traditional land tenure system in Nigeria has long involve soil management practices such as shifting cultivation, slash and burn technique, and traditional tillage methods. These practices have historically played role in maintaining soil physical properties and supporting sustainable productivity (Lal, 2005).

Shifting cultivation also known as swidden agriculture, involves clearing a patch of land, cultivating crops for a certain period, and then allowing the land to lie fallow and regenerate naturally. This fallow period helps to restore soil fertility and allow the land to recover from cultivation. Similarly, the slash and burn involves cutting down vegetation, burning it and using the ash as fertilizers for cultivated crop. This practice has traditionally helped to maintain soil fertility and support sustainable agricultural production (Lal, 2005).

However, due to increasing land use pressure and population growth, the duration of fallow period has significantly decreased. This reduction in fallow duration has resulted to insufficient time for soil fertility restoration, falling below the recommended minimum threshold required for sustainable agricultural practices. As a consequence, soil fertility has been declining, leading to decreased agricultural productivity over time (Mfon , et al., 2014).

The intensification of agricultural practices combined with factors such as urbanization, deforestation and increased demand of land has contributed to the decline in fallow periods and soil fertility. This highlights the need for improved soil management practices that can sustainably address the challenges posed by land use pressure (Mfon , et al., 2014).

To ensure long term sustainability and productivity of Nigeria soil, it is crucial to develop soil management practices that mitigate soil degradation, enhance soil fertility and promote sustainable agricultural systems. This may involve implementing conservation agriculture technique, agro-forestry systems, crop rotation, inter-cropping and the use of organic amendments and fertilizers to restore and maintain soil fertility (Madagoudra & Lokesh, 2021).

Other key soil management practices that play vital role in maintaining soil health and promoting sustainable agriculture include;

Cover cropping which is the planting of specific crops that provide various benefit such as managing soil fertility, conserving water, suppressing weed growth, and controlling pest and diseases. Example of such cover crop include *Mucuna pruriens*, *Centrosema pubescens*, and *Pueraria phaseoloids* (Njira & Nabwami, 2013).

Crop rotation which is the alternating of different crop with varying nutrient requirement on farmland in a planned sequence. Crop rotation help replenish nutrient in the soil such as nitrogen fixation by leguminous plant and reduce the risk of pest and disease buildup (Madagoudra & Lokesh, 2021).

Nutrient management which is the application of organic manure, plant residues and other suitable fertilizers to enhance soil fertility and increase the organic matter content. This improve soil structure, nutrient availability and overall soil function (Njira & Nabwami, 2013).

Reduced tillage or no tillage adopting practices, minimizes soil disturbances during land preparation. This approach helps to retain plant residues on the surface, reduce erosion, preserve soil structure and enhance water infiltration (Lampthey et al., 2018).

Chapter 5

5 Materials and methodology

Two chapters reviewed above presents literatures related to oil palm cultivation, plantations, palm oil extraction processes and treatment of waste from the palm oil industry. Additionally, in chapter four, heavy metal was reviewed, specifically on the sources of the metals, characteristics and the effect to humans and the environment.

This chapter focus on the approach and procedure utilized in this research and investigations. It also includes the framework such as the analytical framework. In the context of this study, the methodological framework covers the study area and field survey, sampling, sample collection, laboratory study with focus on laboratory experimental evaluations, data collection and analysis.

5.1 Study area

The study was done in the southern part of Nigeria, specifically Edo state. Nigeria is situated on the Gulf of Guinea in Western part of Africa with geographical coordinates between longitude 3 degrees and 15 degrees east of the Greenwich meridian and latitude 4 degrees and 14-degrees north of the equator. The country occupies land mass area of approximately 923,768 square kilometers, sharing boundaries with Chad Republic to the North-east, Cameroon to the East, Niger Republic to the North and Benin Republic to the West (Ivarah & Seghosime, 2007).

Edo state, one of the Niger Delta state is located in the South-South geopolitical zone of Nigeria. The state was created on the 27th of August 1991. The state has boundaries with Kogi state to the North, Delta state to the East and South, and Ondo state to the West. Edo state lie between latitude 5.44 degree and 7.34-degree North and longitude 5.4 degree and 6.45-degree East. The state has a land mass of 19,187 square meter with 18 local government area (Asegiemhe, 2019).

This study was carried out in Ikpoba Okha local government area of Edo state in 6 locations tagged as location 1,2,3,4,5,6 and location 1 as the control location. The area of

this study has a tropical climate with two different seasons of wet and dry season. The wet season last between April to October and the dry season occur between November to April with windy (harmattan) period experience between December to January. The average temperature of the area is 25 degrees Celsius in the wet season and 28 degrees Celsius in the dry season. The area is occupied with sandy ferralitic soil with sandy soil texture. The mean annual rainfall and mean relative humidity are 2300mm and 70 percent respectively. The topography of the area is flat.

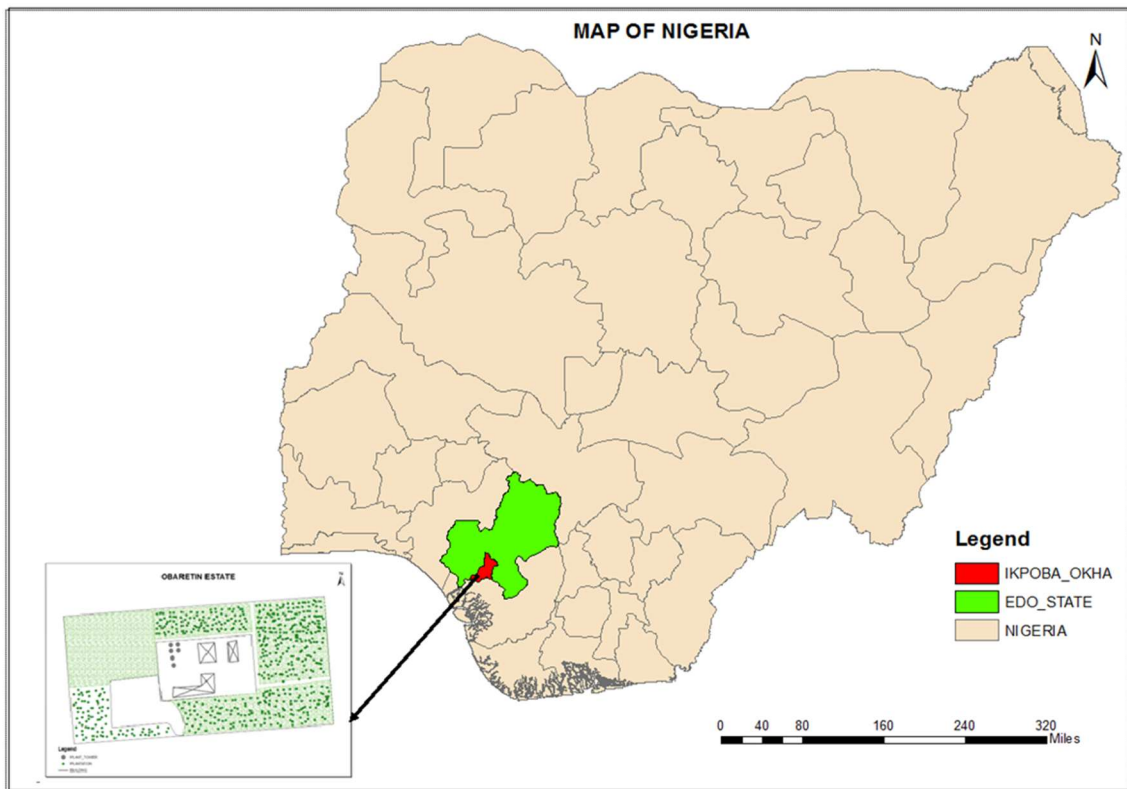


Figure 7: Map of Nigeria showing location of study area

Source: Google map modified

5.2 Field survey and investigation

The varying information gathered from the oil palm plantation are the suitability of the land for the cultivation of the oil palm such as the topography, soil and climatic conditions. The plantation inventory on the number of oil palm trees with their age, health status and productivity were observed. The palm fruit bunch production was surveyed,

specifically the number of bunches per tree, the average bunch weight and the extraction rate of the fruit.

Moreover, the environmental impact assessment of the plantations including soil erosion, chemical applications, water usage and waste management were observed. This assessment helps to ensure the practices on the plantation are suitable and are in compliance with regulation standard of the environment. The social economic aspects of the plantations such as number of employed persons, social amenities provisions for the host community such as water, electricity were recognized. Management practices used in the plantation such as fertilizer application, weed control, harvesting technique were observed.

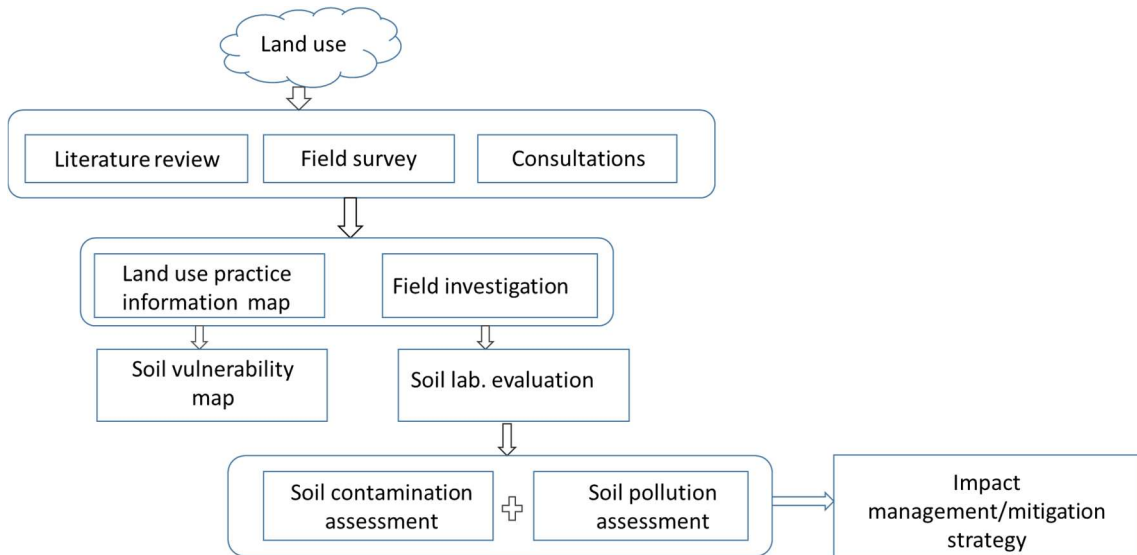


Figure 8: Schematics of methodological framework

5.3 Soil sampling technique

Sampling technique in oil palm plantation depends on the characteristics of the oil palm plantation. Spatial variability of the trees, topography; that is landscape, vegetation is important factor to be considered before choosing the sampling technique in plantations. (Nelson, et al., 2015). Sampling techniques used in sample collection can be random, systematic, stratified, cluster and composite, each with their suitable unique characteristics.

The case study oil palm plantation for this study were characterized with planted tree in equilateral triangular form with spacing of 9 meters apart with 145 oil palm tree per hectares. Random planting technique was used in sample collection. Soil samples were collected randomly within each plantation. This sampling technique was used in order to ensure unbiased representation of the different area in the experimented plantations.

5.4 Sample collection

Soil sample preparation preceded the sample collection. Equipment and materials for sampling were collected and cleaned. Soil sampling auger, zip plastic bags, gloves, tray, spatula were used.

The sampling materials were cleaned to avoid cross-contamination between samples from different plantations. The soil auger was bored down the soil and soil sample were collected at depth 0-15cm, 15-30cm, 30-45cm, 45-60cm, and 60-75cm.

Soil sample were collected from 5 different plantation locations across the region and another control sample was taken. Each sample was replicated 3 times per specific depth, making 15 sample per plantation location. A total of 90 soil sample were collected in overall. Each sample was stored in a clean air tight plastic bag and labelled appropriately with the specific location, depth and the replica. The sample were kept in a cool dry place for preservation before laboratory analysis.



Figure 9: Sample Acquisition (Own Picture)

5.5 Analytical framework - process and procedural approach.

Matured FFB is harvested from the plantation and taken to the palm oil mill for oil extraction. The organic effluent generated from the mill is conveyed to the covered lagoon; anaerobic digestion treatment plant, where microorganism breaks down the organic matter into methane and carbon dioxide. The methane gas is recovered and stored. The methane gas is used as a renewable energy source for electricity generation for the facility consumption as well as fuel for heat application to the boilers in the mill.

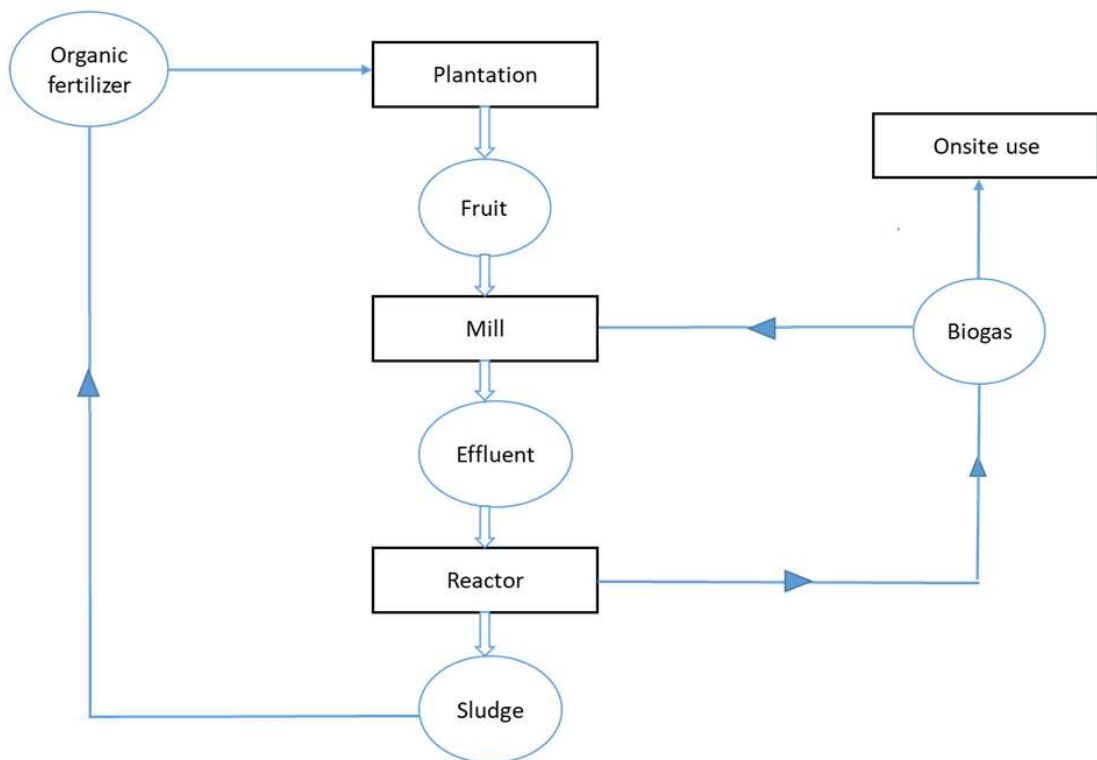


Figure 10: Processes and procedural approach

5.6 Process significance

There are numerous advantages of this sustainable management practice. Among which are the generation of renewable biogas energy use as replacement for fossil fuel, reducing greenhouse gas emission. The environmental impact of the palm oil mill effluent waste is reduced, as the discharge of the untreated POME into water bodies is minimized. Moreover, the methane capture anaerobic digestion treatment process with covered lagoon system reduced methane emissions that could contribute to climate change.

Organic fertilizer obtained improves soil fertility and reduce over dependency on inorganic fertilizers and reduce the effect of nutrient runoff and soil degradation.

However, there could be contamination of the plantation or farmyard soil with heavy metal due to long term application of the slurry from the process. This study tends to answer the question on how sustainable this management process is by ascertaining heavy metal contamination of the plantation via this practice.

5.7 Laboratory analysis

Laboratory analysis of soil sample was carried out in Quality Analytical Laboratory Services Limited; a government approved and certified laboratory, situated in KM 8, Benin/Lagos Express Road, Benin City, Edo state, Nigeria. Determination of the trace elements in the soil sample was carried out using Atomic Absorption Spectrometry after digestion of the soil sample.

5.7.1 Principle of the Atomic Absorption Spectrometry (AAS)

AAS is a common technique for determining the accurate concentration of an element in a sample. Separate analysis is carried out for each element due to their unique wavelength. AAS operates on the principle of measuring light absorption by atom in a gaseous state. The digested sample is first atomized by heating it in a flame or graphite furnace, and a hollow cathode lamp emits light at the analytic element characteristic wavelength. The light passed through the atomize sample and the atom absorb some of the light at specific wavelength unique to each analyzed element. The absorb light is measured using a detector. The difference in intensity between the reference and the sample beam is used to determine the amount of light absorbed by the sample. A calibration curve is established using standard solutions of known concentration. The concentration of the element in the sample is quantified by comparing the measured absorbance to the calibration curve (Welz & Sperlings, 1999).

5.7.2 AAS limitation and recommendations

Result obtained from AAS can be inaccurate due to interference with background absorption of source radiation which is caused by presence of particle from incomplete

atomization. This problem can be solved by increasing the flame temperature. Again, formation of ion instead of atom is capable of causing lower absorption of radiation. This however can be corrected by adding ionization suppressor regenerant such as sulphuric acid or sodium hydroxide (Moustafa, 2012).

AAS has a single elemental analytical principle, as It can only analyze an element per time which can consequently be time demanding (Moustafa, 2012). For example, element such as mercury takes longer time to be analyzed by AAS due to the cold vapour that has to be first generated. Mercury has low vaporization temperature property. The flame or graphite furnace cannot completely vaporize mercury. Moreover, the absorption lines of mercury in the ultra-violet (UV) region are not easily accessible with standard AAS instrument that operates primarily in the visible or near infrared range (Moffett, 2010).

Therefore, for analysis of mercury in this study, Cold Vapour Atomic Absorption Spectrometry (CVAAS) was used. The mercury sample stock was mixed with a reducing agent such as sodium tetrahydroborate in acidic aqueous medium of 5M HCl to reduce mercury ions to elemental mercury vapour. The volatile mercury which was measured by its absorption UV light at a specific wave length of about 253.7nm, was transferred with the help of argon gas to the absorption tube

5.7.3 Apparatus and Reagent used

The apparatus used were 25-250ml conical flask, heater, 100ml volumetric flask, filter paper, funnels, pg instrument AA500F (AAS), concentrated nitric acid and perchloric acid mixture (3:1), 1000mg/l stock standard of Pb, Cu, Zn, Ni, Cd, Mn, Cr, As, Hg, distilled water, PVC hand gloves.

5.7.4 Experimental procedure

1. Sample was placed in a glass petri dish and dried in the oven at 35 degrees Celsius.
2. After 24 hours of drying, the lump present was broken up with a clean glass rod in order to expose the inside for drying.

3. The soil was grinded after drying to fine powder using mortar and pestle. This is done to homogenize the soil in order to ensure uniformity. The sample were sieved in 2mm sieve.
4. 1g of the grinded sample was weighed and placed in a conical flask.
5. 5ml of Nitric-Perchloric acid mixture in ratio (3:1) was added to the flask and allowed to stay overnight.
6. A small glass funnel was inserted to act as reflux condenser and was heated for 1 hour at 150 degrees Celsius. The temperature was raised gradually until 235 degrees Celsius when a dense white fume was observed. Heating was continued for another 2 hours.
7. The flask was removed from the heater and cooled to about 100 degrees Celsius and 1ml of 1:1 HCl was added. This was heated to a white fume until colorless solution was obtained.
8. The colorless solution obtained was poured into 100ml volumetric flask and was rinsed 5 times with water. All the rinsed water was added to the 100ml volume flask in order to make up the volume.
9. Blank solution was prepared using same procedure without any sample. This was done to provide a baseline measurement to account for any background absorbance.
10. The filtrate was analyzed for heavy metal using AAS.

5.7.5 Calibration and analysis

1. Single elemental standards were prepared by dilution of 1000mg/l stock solution of the individual element (Cu, Mn, Zn, Ni, Cr, Pb, As, Cd, Hg).
2. A minimum of 5 standards working solution were prepared daily from the stock solutions.
3. External calibration was used by running de-ionized water and a suite of calibration standard for each element. The calibration curve was then generated for each metal.
4. The digested sample and blank were then run on the AAS to obtained the absorbance values.

5. The concentration of the metals in the sample were calculated from the equation of the calibration curve.

For quality control and assurance, the acidified de-ionized water is first aspirated as blanks in duplicate. Replicate and laboratory control sample were run as quality control sample.

5.8 Quantitative data analysis

Quantitative data analysis approach was used in this study. The approach involves the statistical examination of numerical data in order to identify the pattern, trends and relationship that exist in a data set. The main focus in this approach is the testing of theories and hypothesis which aim to ascertain the association within a numerical data so as to draw significant conclusions (Lutabingwa & Auriacombe, 2007). Research questions, the type of data and the objective of the research usually determine the approach used. In the case of this study, Statistical Package for the Social Sciences (SPSS) software was used in analyzing the data. SPSS engage descriptive analysis to categorize, summarize and describe observations via the generation of the mean, standard deviation, standard error, p-value, and others as required. SPSS conduct Analysis of Variance (ANOVA) in analyzing data set by providing a table with pairwise comparisons between group means. ANOVA compares means between two or more group to ascertain statistical significance between the group means (Lutabingwa & Auriacombe, 2007).

5.9 Analysis of variance (ANOVA)

ANOVA was generated through SPSS statistical package and the Least Significant Difference LSD was used to separate the means at 5 percent level of probability. One-way ANOVA assess significant difference between more than two group means.

However, before ANOVA analysis is carried out, it is imperative that the research hypothesis must have been stated which in many instances always assume the null hypothesis.

The null hypothesis (Ho) state that there is no significant difference between the group means, that is the mean values in the different groups are the same

$$H_0: \mu_1 = \mu_2 = \mu_3 = \dots = \mu_n \quad (\text{equation 1})$$

On the other hand, the alternative hypothesis (HA) state that at least one of the group means is different

$$H_A: \mu_1 \neq \mu_2 \neq \mu_3 \neq \dots \neq \mu_n \quad (\text{equation 2})$$

Where; μ = group mean and n = number of groups for both cases.

If there is a statistical significance in at least one of the group mean, then the null hypothesis is rejected. On the other hand, if there is no statistical significant (difference) between the group means, then we fail to reject the null hypothesis.

The null hypothesis is rejected if the P-value from the conducted ANOVA is less than the significant level of alpha (α) at 5% level of probability. This implies one of the group mean is different.

5.9.1 Fishers LSD post hoc test

Post hoc test is generally carried out after the null hypothesis is rejected ($p < \alpha$). The result of the analysis of variance only show if there is a significant difference among the group means and not the group whose mean is different. Hence, the post hoc test is done to show the particular means that are significantly different. Among the post hoc test use frequently in research after ANOVA are Fishers (LSD), Turkey Honestly Significance Different (HSD), Bonferroni and Scheffe post hoc test. The post hoc test selected by the researcher depends on the data to be analyzed, the research questions. For this study, Fishers LSD post hoc test was used due to its simplicity, control over type I error and ease of interpretation (Hilton & Armstrong, 2006).

LSD test can be calculated for pair wise comparison using the equation below

$$LSD = t_{0.025, DF_w} * \sqrt{MS_w (1/n_1 + 1/n_2)} \quad (\text{equation 3})$$

Where;

$t_{0.025, DF_w}$ = t-critical value from the t distribution table with $\alpha = 0.025$

DF_w = the degree of freedom within the group from the ANOVA table

MS_w = the mean squares within the group from the ANOVA table

n_1, n_2 = sample size of each group.

If the absolute mean difference between two group means are greater than the LSD, conclusion can be drawn that there is significant difference. However, if the difference between two group means are less than the LSD value, conclusion can be drawn that there is no significant difference.

5.10 Cluster analysis

Cluster analysis is a statistical technique used to classify objects of similarities into groups called cluster. The similarities between object is obtain using a distance matrix. SPSS generates clusters analysis output through a dendrogram which is the main output. The dendrogram group the objects into cluster according to similarities. The main approach is to identify the two cluster that are closest together in similarities and merge them together. Two distinct types of cluster analysis use in statistical analysis to group objects are hierarchical and non-hierarchical (k-means) (Forina et al., 2002).

Hierarchical cluster was used in this studies due to its informative and interpretable property. Moreover, it is easier to determine the number of clusters by hierarchical clustering dendrogram and it can be used for unknown number of classes.

5.11 Contamination factor and degree of contamination

Contamination factor assess the degree of contamination in a sample (soil, water, plant), site or location. Its principle is based on quantitative measurement of the concentration in a specific pollutant in relation with the background level. Contamination factor is effective in checking the environment, assessing the risk and proffering remediation technique (Shakery et al., 2010).

Contamination factor is determined with the equation adopted from (Harikumar, et al., 2009)

$$C_f^i = C_{o-1}^i / C_n^i \quad (\text{equation 4})$$

where;

C_{o-1}^i = mean concentration of each metal in soil

C_n^i = Baseline or background value in unpolluted soil

C_f^i = contamination factor

The degree of contamination is determined by summation of all contamination factor using the equation given by (Adamu & Nganje , 2010)

$$C_d = \sum_{i=1}^n C_f^i \quad (\text{equation 5})$$

where;

n = number of analyzed element

I = ith element (pollutant)

C_f = contamination factor

5.12 Pollution load index

Pollution load index is used to determine the pollution level in a specific site or location. It is calculated using the equation given by Benarabi et al., 2021

$$PLI = \sqrt[n]{CF_1 \times CF_2 \times CF_3 \times \dots \times CF_n} \quad (\text{equation 6})$$

Where;

CF = contamination factor, n = number of analyzed element.

Table 18: Contamination factor

Category	CF value	Contamination level
1	CF<1	Low contamination
2	1<CF<3	Moderate contamination
3	3<CF<6	Considerable contamination
4	CF>6	Very high contamination

Source: (Benarabi et al., 2021)

Table 19: Degree of contamination

Category	Cd value	Degree Contamination level
1	Cd<6	Low degree of contamination
2	6d<12	Moderate degree of contamination
3	12d<24	Considerable degree of contamination
4	Cd>24	High degree of contamination

Source: (Adamu & Nganje, 2010; Ogeleka & Alaminiokuma, 2020)

Table 20: Pollution load index

Category	PLI value	Pollution level
1	$PLI < 1.5$	Very low pollution
2	$1.5 \leq PLI < 2$	Low pollution
3	$2 \leq PLI < 4$	Moderate pollution
4	$4 \leq PLI < 8$	Significant pollution
5	$8 \leq PLI < 16$	Very high pollution
6	$16 \leq PLI < 32$	Extremely high pollution
7	$PLI \geq 32$	Excessive pollution

Source: (Benarabi et al., 2021)

Chapter 6

6 Results and discussions

This chapter presents and discusses the results and findings of the study ‘investigation of the accumulation effects of trace elements in oil palm plantation soils fertilized with anaerobically treated palm oil mill effluent in southern Nigeria’ with analysis and interpretation of data obtained.

The results of heavy metals (Cu, Mn, Zn, Ni, Cr, Pb, Cd, As, Hg) mean concentrations in different locations ranging from location 1 to location 6 of the oil palm plantation soil fertilized with sludge from POME are depicted in table 21-38 where location 1 represent the control or baseline soil.

Table 21: Copper (Cu) mean concentration (mg/kg) across locations per depth (cm)

Location	Depth(cm)				
	0-15	15-30	30-45	45-60	60-75
Location 1 (ctrl)	8.61a	6.72a	6.72a	6.72b	4.52c
Location 2	14.06b	12.16d	10.24c	9.25e	8.56e
Location 3	16.72c	12.16d	11.56d	7.96d	6.72d
Location 4	17.76d	13.32e	12.16e	6.72b	1.12a
Location 5	12.16e	8.82b	7.14b	7.60c	1.14a
Location 6	12.16e	8.54c	6.72a	5.88a	1.54b

Mean in the same column followed by different letters in superscript are significantly different at the 5% level using Least Significant Difference (LSD)

Table 22: Analysis of variance for copper

		Sum of Squares	df	Mean Square	F	Sig.
0-15	Between Groups	168.888	5	33.778	16476.902	.000
	Within Groups	.025	12	.002		
	Total	168.913	17			
15-30	Between Groups	102.429	5	20.486	6025.224	.000
	Within Groups	.041	12	.003		
	Total	102.470	17			
30-45	Between Groups	95.654	5	19.131	5265.347	.000
	Within Groups	.044	12	.004		
	Total	95.697	17			
45-60	Between Groups	20.985	5	4.197	1169.464	.000
	Within Groups	.043	12	.004		
	Total	21.028	17			
60-75	Between Groups	152.820	5	30.564	12091.276	.000
	Within Groups	.030	12	.003		
	Total	152.851	17			

From table 21, Cu reported different letters across the column (locations). This shows that Cu is significantly different at ($p < 0.05$) levels across the location as shown in table 22. Mean copper content of the experimented soils (Location 2 to Location 6) showed significant difference with the location 1 (control) in 0-15, 15-30 and 60-75 soil depth. In soil depth 30-45, similarities exist in the location 6 and the location 1 and in soil depth 45-60, similarities also exist in location 4 and location 1 which revealed that POME treatment does not have effect on location 6 (30-45) and location 4 (45-60). The column 0-15 soil depth with different location reported different letter across the column. This connote that the concentration of Cu across the column is significantly different from one another at ($p < 0.05$) levels. An examination of the table 21 at column (0-15cm) shows that location 1, location 2, location 3 and location 4 have different letters indicating significant difference between the four locations with no similarities. Location 5 and location 6 have same letter indicating that the copper content is similar across the two

locations. The column with different location at 15-30 depth reported significant difference across the location at ($p < 0.05$) level. Location 1, location 4, location 5 and location 6 reported different letters depicting significance difference between the four locations, implying no similarities among the soils of these locations. Location 2 and location 3 reported same letter which implies the copper content is similar in these two locations. The column at 30-45 soil depth reported different letters with implications of significant difference in the different soil locations at ($p < 0.05$) level. Location 2, location 3, location 4 and location 5 show different letters which connotes the 4 soil locations at this depth are significantly different with no similarities. Location 1 and location 6 show same letter with depiction of similarities between the two locations. The column at 45-60 soil depth reported different letters in some locations. This result shows that the Cu content at this depth differ significantly across the location at ($p < 0.05$) levels. The results revealed that location 1 (control) and location 4 have same Cu content in these locations while location 2, location 3, location 5 and location 6 with different letters shows there is significant different among the soils of these four locations. The column at 60-75 soil depth reported different letters with implication of significant difference across the column at ($p < 0.05$) level. Location 1, location 2, location 3 and location 6 reported different letters which implies no similarities across these locations. Location 4 and location 5 reported same letter which implies the soil have similarities in content.

From the table 21, Cu has its highest top soil concentrations (17.76mg/kg) in location 4 and the lowest top soil content in location 5 and location 6 (12.16mg/kg). The highest bottom soil content was in location 2 (8.56mg/kg) and the lowest bottom soil content (1.12mg/kg) was in location 4. Mean concentration of Cu in all locations and in all depth was far below the maximum permissible value for the European Union (EU) (140mg/kg) and the Nigeria Federal Environmental Protection Agency (FEPA) (80mg/kg) standard (Mohammed & Folorunsho, 2015). The low Cu level content compared to these standards could be attributed to the low initial content of Cu in treated POME. (Osman et al., 2020) reported (6.69 \pm 0.32ppb) concentration of Cu in treated POME. (Hashiguchi, et al., 2021) reported (0.10-0.32mg/L) of Cu content in treated POME. This implication shows that POME sludge has natural low Cu content. According to (Taariq-Sidibe, et al., 2020), sludge high in Cu content can result to accumulation when continuously applied to soil. (Haruna et al., 2021) reported that low Cu concentration in

soil could be obtained upon dilution of treated POME with deionized water. Study done by (Ako & Anegebe, 2022) reported a range of (31.04-37mg/kg) and (35.52-43.87mg/kg) of Cu content in the soil treated with POME sludge in South-south region of Oghareki, Oghara, which is about 30KM from the case study soil. (Sha'Ato et al., 2012) reported Cu content range of (2.72-49.8mg/kg) in POME treated soil in lower Benue valley central region of Nigeria. (Chude & Obigbesan, 1982) reported Cu content range of (15-52mg/kg) in South-western region of Nigeria soil. (Kparmwang et al., 2008) reported Cu content range of (15-65mg/kg) in savannah soil in Northern Nigeria. The difference of Cu content in the different locations and regions could be as result of the varying physico-chemical properties of the soil (Xu, et al., 2022). (Chinyere et al., 2018) reported that Cu concentration in soil was affected by POME. (Zhuang et al., 2009) reported that Cu in soil is mostly traceable to copper ore processing and mining. According to (Taariq-Sidibe, et al., 2020), when total Cu exceeds 50ppm in sandy soil, up to 150ppm for silty clay or clayey soil, toxicity to plant roots could occur.

Table 23: Analysis of variance for Manganese

		Sum of Squares	df	Mean Square	F	Sig.
	Between Groups	1379.648	5	275.930	79979.597	.000
0-15	Within Groups	.041	12	.003		
	Total	1379.689	17			
	Between Groups	429.660	5	85.932	16578.538	.000
15-30	Within Groups	.062	12	.005		
	Total	429.723	17			
	Between Groups	386.820	5	77.364	21895.497	.000
30-45	Within Groups	.042	12	.004		
	Total	386.863	17			
	Between Groups	659.573	5	131.915	25531.860	.000
45-60	Within Groups	.062	12	.005		
	Total	659.635	17			
	Between Groups	649.534	5	129.907	7516.310	.000

60-75	Within Groups	.207	12	.017
	Total	649.742	17	

Table 24: Manganese (Mn) mean concentration (mg/kg) across locations per depth (cm)

Location	Depth(cm)				
	0-15	15-30	30-45	45-60	60-75
Location 1 (ctrl)	49.02d	34.98d	30.96b	27.00c	17.49b
Location 2	55.29e	42.75e	42.75d	30.10d	24.75e
Location 3	36.49c	30.21a	36.48c	26.88c	19.53d
Location 4	34.98b	42.75e	30.96b	17.67a	4.94a
Location 5	36.48c	32.64b	30.21a	36.48e	19.08c
Location 6	30.21a	33.48c	30.21a	21.12b	17.60b

Mean in the same column followed by different letters in superscript are significantly different at the 5% level using Least Significant Difference (LSD)

From table 24, Mn reported different letters across the column (locations). This revealed that Mn is statistically significant at ($p < 0.05$) level across the column as depicted in table 23. Mean Mn content of the experimented soils (Location 2 to Location 6) showed significant difference with the location 1 (control) in 0-15, and 15-30 soil depth. In soil depth 30-45, similarities exist in the location 4 and the location 1. In soil depth 45-60, similarities also exist in location 3 and location 1. Similarities also exist in location 6 and location 1 (control) for depth 60-75cm. These revealed that POME treatment does not have effect on location 4 (30-45), location 3 (45-60) and location 6 (60-75). The first column; 0-15 soil depth with different location reported different letters in location 1, location 2, location 4 and location 6 with implication of significant difference across the location with no similarities. Location 3 and location 5 reported same letter with implications of similarities in content of the locations. The second column at 15-30 depth reported different letters with implication of significant difference

across the column at ($p < 0.05$) level. Location 2 and location 4 have the same letter showing that Mn concentration for both soil locations are similar. Location 1, location 3, location 5 and location 6 have different letters indicating that Mn were not the same for these locations. The third column at 30-45 depth reported different letters across the column. The results show that the Mn concentration at this depth differs significantly across column at ($p < 0.05$) level. The results revealed that location 1, location 2, location 3 and location 4 with different letters shows the soil in these locations are statistically significant. Location 5 and location 6 reported the same letter which shows there is similarities in content for both locations. The fourth column 45-60 soil depth, reported different letters across the column at ($p < 0.05$) level. Location 1 and location 3 reported same letter which implies both locations have similar content. Location 2, location 4, location 5 and location 6 reported different letters which reveals no similarities across these locations. The fifth column at 60-75 soil depth reported different letter at ($p < 0.05$) level with implication of significant difference across the column. Location 1 and location 6 reported same letter with indication of similarities in Mn concentration of both locations. Location 2, location 3, location 4, and location 5 reported different letters with depiction of significance difference across the locations.

Concentration of Mn had the highest concentration both in background soil and the experimented soil among all the heavy metal investigated. These values suggest that the soil concentration of Mn is sufficient for agriculture according to the rating of (Esu, 1991) as the Mn is above critical level of (1-5mg/kg). (Aubert, 1977) reported that Manganese had the highest natural concentration of metal in soil more than other heavy metals. Higher concentration of Mn metal is influenced and enhanced by the organic matter and acidity of the soil. Organic matter complexes with Mn, thereby promoting its accumulation in the soil. Soil with acidic pH condition increases the concentration of Mn compared to other metals (Anjali et al., 2018). High Mn content in soil could be connected to acidic nature of the soil in this area. (Khairuddin, et al., 2016) reported highest Mn concentration in treated POME than other metals which could variably resulted to the highest Mn soil concentration. (Murtaza et al., 2003) reported that higher concentration of Mn in soil compared to other metals could be due to the easy mobility and accumulation of Mn in soils. (Hong, et al., 2010) reported that Mn is more frequent at a low pH below 5, reduced under dry soil condition and likely to be deficient in organic

soil. From table 24, the highest value of top soil Mn was reported in location 2 (55.29mg/kg) and the highest bottom soil Mn was in location 4 (4.94mg/kg) while the highest bottom soil Mn was location 2 (24.75mg/kg) and lowest bottom soil Mn content was reported in location 4 (4.94mg/kg). Mn content in this study when compare to the standard (80-7000mg/kg) set by (Alloway, 1990) was low. it can be deduced that the amount of Mn in both top soil and bottom soil were within safe limit.

Table 25: Analysis of variance for Zinc

	Depth	Sum of Squares	df	Mean Square	F	Sig.
0-15	Between Groups	570.880	5	114.176	21143.704	.000
	Within Groups	.065	12	.005		
	Total	570.945	17			
15-30	Between Groups	757.797	5	151.559	3425.933	.000
	Within Groups	.531	12	.044		
	Total	758.328	17			
30-45	Between Groups	1602.515	5	320.503	37929.350	.000
	Within Groups	.101	12	.008		
	Total	1602.616	17			
45-60	Between Groups	1126.447	5	225.289	44174.410	.000
	Within Groups	.061	12	.005		
	Total	1126.509	17			
60-75	Between Groups	421.652	5	84.330	135531.014	.000
	Within Groups	.007	12	.001		
	Total	421.660	17			

Table 26: Zinc (Zn) mean concentration (mg/kg) across location per depth (cm)

Location	Depth(cm)				
	0-15	15-30	30-45	45-60	60-75
Location 1(ctrl)	31.38c	15.68a	15.68a	7.84a	6.40a
Location 2	23.54a	23.54b	21.47c	20.59d	19.51f
Location 3	31.38c	24.17b	15.68a	15.38b	13.94b
Location 4	39.22d	37.62c	34.42d	23.54f	15.58c
Location 5	25.14b	23.54b	21.30c	21.62e	18.42e
Location 6	23.54a	23.54b	20.34b	16.82c	15.87d

Mean in the same column followed by different letters in superscript are significantly different at the 5% level using Least Significant Difference (LSD)

From table 26, Zn reported different letters across the column (locations). This revealed that Zn is statistically significant at ($p < 0.05$) across the location as noticed in table 25. Column 0-15 soil depth reported different letters indicating that Zn in the different soil locations differ significantly from one another at ($p < 0.05$). The location 1 and location 3 were similar. The result also shows similar letter for location 2 and 6 indicating that both location have similar concentration. Location 4 and location 5 reported different letters indicating difference in Zn content in both locations. Column 15-30 soil depth reported different letters for Zn across the column which means that Zn differed significantly at ($p < 0.05$) amongst the soil locations. From the table 26, location 2, location 3, location 5 and location 6 have similar Zn content and were significantly different from location 1 and location 4. Column 30-45 soil depth reported different letters for Zn indicating that Zn differed significantly among the location at ($p < 0.05$) level. Location 1 and location 3 have the same letter with indication of similar Zn content. Location 4 and location 6 have different letter which indicate significance difference between the locations and the other locations. Column 45-60 soil depth reported different letters for Zn indicating Zn differed significantly at ($p < 0.05$). Location 1, location 2, location 3, location 4, location 5 and location 6 shows different letters which indicates significant difference across the soil location with no similarities. Column 60-75 soil

depth reported different letters for Zn indicating Zn differed significantly at ($p < 0.05$). Location 1, location 2, location 3, location 4, location 5 and location 6 shows different letters which indicates significant difference across the soil location with no similarities.

From the table 26, Zn had its highest top soil content in location 4 (39.22mg/kg) and the highest bottom soil content in location 2 (19.51mg/kg). The lowest top soil content of Zn was in location 2 and location 6 (23.54mg/kg) and the lowest bottom soil of Zn was in location 1 (6.40mg/kg). From the (Alloway, 1990) permissible standard of Zn (50mg/kg), the soil Zn content in the case study was below standard. (Alloway, 2008) attributed Zn deficiency in soil to high pH and its excess in soil to geological and anthropogenic activity. The concentration of Zn in anaerobic digested treated POME according to (Khairuddin, et al., 2016) was 131.11 + 3.49ppm. Though Zn concentration of POME could vary in amount with the treatment processes engaged and the source of the oil palm fruit (Izah et al., 2016). Treated POME with high concentration of Zn could variably increase the amount of Zn concentration in the soil. (Chinyere et al., 2018) reported that POME could affect the soil with higher exchange acidity and cation exchange capacity (CEC). Increase in CEC could reduce the Zn content in soil as a result of increase nutrient sorption (Chukwuma et al., 2010). The high organic matter content of POME (Ohimain et al, 2012) could increase the organic matter content of the soil (Nmaduka et al., 2018). Organic matter could bind with Zn increasing the Zn content in the soil. (Ganoë, et al., 2007) reported from studies that Zn is less as pH increases usually above 7.4, likely to be deficient under cool soil temperature, high organic matter soil contain low levels of Zn and low organic matter soil retain less Zn.

Table 27: Analysis of variance for Nickel

	Depth	Sum of Squares	df	Mean Square	F	Sig.
0-15	Between Groups	553.099	5	110.620	406358.139	.000
	Within Groups	.003	12	.000		
	Total	553.102	17			
15-30	Between Groups	765.899	5	153.180	2540.295	.000
	Within Groups	.724	12	.060		
	Total	766.622	17			
30-45	Between Groups	290.026	5	58.005	29411.132	.000
	Within Groups	.024	12	.002		
	Total	290.050	17			
45-60	Between Groups	487.780	5	97.556	240549.088	.000
	Within Groups	.005	12	.000		
	Total	487.785	17			
60-75	Between Groups	126.204	5	25.241	518.471	.000
	Within Groups	.584	12	.049		
	Total	126.789	17			

Table 28: Nickel (Ni) mean concentration (mg/kg) across location per depth (cm)

Location	Depth(cm)				
	0-15	15-30	30-45	45-60	60-75
Location 1 (ctrl)	13.54b	10.24a	8.35a	7.90b	7.24a
Location 2	24.55e	23.60c	20.00f	19.05e	14.45d
Location 3	26.55f	24.95d	14.45e	20.00f	11.45c
Location 4	13.83c	10.40a	9.95c	9.95d	8.60b
Location 5	14.90d	10.40a	11.45d	8.90c	7.44a
Location 6	13.33a	10.83b	8.98b	7.68a	7.60a

Mean in the same column followed by different letters in superscript are significantly different at the 5% level using Least Significant Difference (LSD)

From table 28, Ni reported different letters across the columns. This points that Ni is statistically significant at ($p < 0.05$) as shown in table 27. The column 0-15 with different locations reported different letter for Ni with indication that Ni is statistically significant at ($p < 0.05$). Location 1, location 2, location 3, location 4, location 5 and location 6 show different superscript which indicates significance difference across the location with no similarities. Column 15-30 show different letters for Ni across the location with implication of significance difference at ($p < 0.05$). Location 1, location 4 and location 5 show the same letter indicating similarities in content. Location 2, location 3 and location 6 show different letters which indicates significance difference among the location. Column 30-45 reported different letters showing significance difference exist across the location at ($p < 0.05$). Location 1, location 2, location 3, location 4, location 5 and location 6 show different letter which indicates significance difference across the locations with no similarities. Column 45-60 reported different letters implying significance difference exist across the location at ($p < 0.05$). Location 1, location 2, location 3, location 4, location 5 and location 6 show different letter with implication of significance difference across the locations with no similarities. Column 60-75 reported different letters implying significance difference across the location at ($p < 0.05$).

Location 1, location 5, location 6, show the same letter with indication of similarities. location 2, location 3 and location 4 show different letter with implication of significance difference across the locations with no similarities.

From the table 28, Ni had its highest top soil content among the treated soil in location 3 (26.55mg/kg) and its lowest top soil value in location 6 (13.33mg/kg). The highest value of Ni in the bottom soil among the treated locations was observed in location 2 (14.45mg/kg) and the lowest bottom soil content was in location location 5 (7.44mg/kg). An observation of decrease in content of Ni from top soil to bottom soil was experienced in all locations. Nickel is an essential micronutrient (Marchner, 1995). Nickel is required in small amount in soil for development to be normal in plant (Fernando, et al., 2016). Excessive Ni uptake by plant could be detrimental. Nickel contamination in soil is majorly from sewage sludge and fertilizer (Smiljanic, et al., 2019; Alloway, 1990). The regulatory standard of Ni of some countries across the globe as reported by (Bakshi et al., 2018) are Australia (60mg/kg), Canada (100mg/kg), China (40-60mg/kg), Tanzania (100mg/kg), Netherlands (100mg/kg), USA (72mg/kg). Nickel availability in soil varies widely as a function of soil pH. (Cempel & Nikel, 2006) reported that the increase solubility and mobility of Ni resulted from decrease pH. Ni deficiency likely occur in high pH soil above pH 6.7 and high organic matter soil. Ni range of 1-20mg/kg is considered healthy productive soil (Chun, 2019). The moderate initial concentration of Ni in the untreated soil showed that the soil in this area or region is moderately concentrated in Nickel. This could be as a result of the geological composition or parent material of the area or location (Zhang & Wang, 2020). (Khairuddin, et al., 2016) reported (10.77 + 0.15 ppm) as Ni concentration in treated POME, while (Osman et al., 2020) reported Ni content of (11.65 ± 0.48ppb) in treated POME. This conditions could result to moderate Ni Content in the treated soil with POME.

Table 29: Analysis of variance for Lead

		Sum of Squares	df	Mean Square	F	Sig.
0-15	Between Groups	6.113	5	1.223	349.329	.000
	Within Groups	.042	12	.004		
	Total	6.155	17			
15-30	Between Groups	2.844	5	.569	320.973	.000
	Within Groups	.021	12	.002		
	Total	2.865	17			
30-45	Between Groups	6.817	5	1.363	26.674	.000
	Within Groups	.613	12	.051		
	Total	7.430	17			
45-60	Between Groups	2.284	5	.457	237.646	.000
	Within Groups	.023	12	.002		
	Total	2.307	17			
60-75	Between Groups	1.141	5	.228	127.539	.000
	Within Groups	.021	12	.002		
	Total	1.162	17			

Table 30: Lead (Pb) mean concentration (mg/kg) across location per depth (cm)

Location	Depth(cm)				
	0-15	15-30	30-45	45-60	60-75
Location 1	1.06a	1.02b	1.02a	0.60a	0.51a
Location 2	2.65e	1.74d	1.04a	0.78b	0.79c
Location 3	1.82c	0.41a	2.58b	1.62d	1.25d
Location 4	2.51d	1.04b	0.94a	0.68a	0.61b
Location 5	1.82c	1.32c	1.11a	1.04c	0.65b
Location 6	1.27b	1.04b	0.70a	0.63a	0.53a

Mean in the same column followed by different letters in superscript are significantly different at the 5% level using Least Significant Difference (LSD)

From table 30, Pb reported different letters across the columns. This reveal that Pb is statistically significant at ($p < 0.05$) level as observed in table 29. The column 0-15 with different locations reported different letters for Pb with indication that Pb is statistically significant at ($p < 0.05$). Location 3 and location 5 show the same letter with indication of similarities in content. Location 1, location 2, location 4 and location 6 show different letters which indicate significant difference among the location. Column 15-30 reported different letters for Pb with indication of significant difference at ($p < 0.05$). Location 1 and location 6 show the same letter means similarities exist in content. Location 2, location 3, location 4 and location 5 show different letters which indicates these locations are statistically significant. Column 30-45 reported different letters for Pb with indication of significant difference at ($p < 0.05$). Location 1, location 2, location 4 and location 5 and location 6 show the same letter with implication of similarities in content. Location 1 shows different letters which reveals significant difference among the other soil locations. Column 45-60 soil depth reported different letters with implications of significant difference across the column at ($p < 0.05$). Location 1, location 4 and location 6 have same letter which implies similar content condition of Pb. Location 2, location 3, and location 5 with different letters shows there is a significant difference among the soil of these locations. Column 60-75 soil depth reported different letters with implications of significant difference across the column at ($p < 0.05$). Location 1, location 6 show the same letter with indication of similarities. location 4 and location 5 reported same letters which implies same content condition of Pb among these two locations. Location 2 and 3 show different letter which indicates significant difference.

From the Pb table 30, Highest mean content of Pb in top soil among the treated soil was observed in location 2 (2.65mg/kg) and the lowest top soil value was obtained in location 6 (1.27mg/kg). The highest bottom soil Pb content was observed in location 3 (1.25mg/kg) and the lowest bottom soil was observed in location 6 (0.53mg/kg). At the control location, Pb detected across the soil depth at lower concentration compared to the treated soil. A decrease trend in content was observed from the top soils down to the bottom soils in all locations except in location 3 where the sub soil layer (0.41mg/kg) was quite lower than the mid layer soil (2.59mg/kg). The level of Pb content was below the regulatory standard of USA (300mg/kg), UK (70mg/kg), EU (300mg/kg) and WHO (0.3-10mg/kg) as reported by (Ediene & Umoetok, 2017). The ranges of uncontaminated soil

of (2-200mg/kg) was reported by (Nangia , 1991). The low level of Pb in the baseline and treated soils could be as a result of absence of Pb in the soil parent or geological composition of soil in this area (Zhang & Wang, 2020). Moreover, POME does not contain a high level of Pb, hence could only introduce small amount of Pb into the soil. However, continuous application could potentially increase the Pb content over time (Mortvedt, 1995). (Khairuddin, et al., 2016) reported Pb content of (0.38 + 0.10ppm) in anaerobic digestion POME treated sludge, while (Osman et al., 2020) reported Pb content of treated POME as (0.19 ± 0.01ppb) which justifies low Pb content in the soil. Soil properties such as pH, Organic matter and CEC of the soil have strong influence on the mobility of Pb in soil. (Henry , 2000) reported that the pH of soil affects the Pb content of the soil. (Martinez & Motto, 2000) reported that the CEC of the soil absolutely determines the dynamics of Pb in the soil. (Chinyere et al., 2018) reported that organic matter affects the mobility of the Pb in soil via immobilization. The enormous content of Pb in the soil or the small content of Pb in soil is controlled by the CEC, pH and organic matter content of the soil. Soil with low pH and low CEC led to an increase of Pb in the soil while the soil with high organic matter led to low Pb content in the soil (Adriano, 2001).

Table 31: Analysis of variance for Cadmium

		Sum of Squares	df	Mean Square	F	Sig.
A	Between Groups	.456	5	.091	24.897	.000
	Within Groups	.044	12	.004		
	Total	.500	17			
B	Between Groups	.540	5	.108	58.501	.000
	Within Groups	.022	12	.002		
	Total	.562	17			
C	Between Groups	.176	5	.035	789.825	.000
	Within Groups	.001	12	.000		
	Total	.176	17			
D	Between Groups	.055	5	.011	151.646	.000
	Within Groups	.001	12	.000		
	Total	.056	17			

E	Between Groups	.011	5	.002	29.246	.000
	Within Groups	.001	12	.000		
	Total	.011	17			

Table 32: Cadmium (Cd) mean concentration (mg/kg) across location per depth (cm)

Location	Depth(cm)				
	0-15	15-30	30-45	45-60	60-75
Location 1(Ctrl)	0.33a	0.23a	0.10a	0.10a	0.10a
Location 2	0.41a	0.28a	0.20b	0.20c	0.15c
Location 3	0.49b	0.41b	0.31d	0.25d	0.16c
Location 4	0.68c	0.70c	0.41e	0.22c	0.13b
Location 5	0.52b	0.45b	0.24c	0.20c	0.10a
Location 6	0.80d	0.65c	0.20b	0.12b	0.12a

Mean in the same column followed by different letters in superscript are significantly different at the 5% level using Least Significant Difference (LSD)

From table 32, Cd reported different letters across the column with implication that Cd is significantly different at ($p < 0.05$) as shown in table 31. The column 0-15 soil depth reported different letters for Cd with indication of significant difference at ($p < 0.05$). Location 1 and location 2 have same letter with indication of similarities in concentration. Location 3 and location 5 reported same letter which reveals similarities in content of Cd among these locations. Location 4 and location 6 have different letter from other locations indicating significant difference from the other location. Column 15-30 reported different letters with implication that Cd is statistically significant at ($p < 0.05$). Location 1 and location 2 have same letters which reveals similarities in content of Cd among these locations. Location 3 and location 5 have same letters which implies similar content in Cd. Location 4 and location 6 have same letter which indicates similarities. Column 30-45 reported different letters with implications that Cd is statistically significant at ($p <$

0.05). Location 2 and location 6 have same letters with indication of similar Cd content condition among this location. Location 1, location 3, location 4 and location 5 have different letters with implication of significant differences in content of this locations. Column 45-60 reported different letters with implications that Cd is significantly different at ($p < 0.05$). Location 2, location 4 and location 5 have same letter with indication of similarities in Cd content. Locations 1, location 3 and location 6 reported different letters with implication of significant difference among the Cd contents in the locations. The column 60-75 soil depth reported the same letters in location 1, location 5 and location 6 with implication of no significance difference among the location. Location 2 and location 3 also reported same letter with indication of similarities in Cd content. Location 4 reported different letter which implies significant difference from the other locations.

From the Cd table 32, Cd was detected in low amount in the background or control soil (location 1) across the soil depth. The Cd contents in the treated soil was more than the background level with implication of contamination from the anthropogenic sludge additions. The highest mean content of Cd in the top soil among the treated, was (0.80mg/kg) in location 6 and the lowest top soil was observed in location 2 (0.41mg/kg). The highest bottom soil Cd content was observed in location 3 (0.16mg/kg) and the lowest bottom soil Cd content was in location 5 (0.10mg/kg). A decrease in Cd content was observed down the soil depth from the top soil (0-15cm) to the bottom soil (60-75cm). The maximum permissible limit of Cd was below the set level of EU standard (3.0mg/kg), UK (1.4mg/kg), USA (400mg/kg) except for the highest mean top soil of (0.80mg/kg) observed in location 6 which was above the (0.002-0.5mg/kg) set standard of WHO according to (Ediene & Umoetok, 2017). The (0.01-0.7) ranges of Cd uncontaminated soil according to (Nangia , 1991) was below the highest mean content of Cd of (0.80mg/kg) in location 6. Therefore, the soil of location 6 at 0-15cm could be said to be contaminated with Cd following this standard and the WHO standard. The low Cd content in background or baseline soil of location 1 could be as a result of the soil parent material of the region (Zhang & Wang, 2020). The main source of anthropogenic contamination of soil with Cd is via mining (Kar et al., 2008). The content of Cd in treated POME can positively or negatively affects the content of Cd in soil when used as fertilizer (Wang et al., 2022). (Khairuddin, et al., 2016) reported Cd content of (0.41 + 0.01ppm) in treated POME while (Osman et al., 2020) reported (0.053 ± 0.02ppb) of Cd in treated POME for

discharge. Continuous or long-term application of POME to the soil could result to the increase of Cd in the soil through bio-accumulation property of heavy metal (Ohimain et al., 2012). Soil treated with POME tends to have high organic matter due to the highly organic nature of POME (Ohimain & Izah, 2014). (Gray et al., 1999; Liao, 2006) reported soil organic matter as the most important soil component controlling the sorption and desorption of Cd. (Chen et al., 2000) reported Cd as the most mobile and soluble when compared to other metals. Soil with high organic matter content immobilized Cd strongly through the process of adsorption (Mustafa et al., 2004).

Table 33: Analysis of variance for chromium

	Depth	Sum of Squares	df	Mean Square	F	Sig.
0-15	Between Groups	9.736	5	1.947	320.383	.000
	Within Groups	.073	12	.006		
	Total	9.809	17			
15-30	Between Groups	4.990	5	.998	2041.191	.000
	Within Groups	.006	12	.000		
	Total	4.995	17			
30-45	Between Groups	2.495	5	.499	48.954	.000
	Within Groups	.122	12	.010		
	Total	2.618	17			
45-60	Between Groups	.505	5	.101	15.012	.000
	Within Groups	.081	12	.007		
	Total	.585	17			
60-75	Between Groups	.460	5	.092	17.375	.000
	Within Groups	.064	12	.005		
	Total	.524	17			

Table 34: Chromium (Cr) mean concentration (mg/kg) across location per depth.

Location	Depth(cm)				
	0-15	15-30	30-45	45-60	60-75
Location 1(Ctrl)	0.78a	0.69a	0.44a	0.35a	0.31a
Location 2	2.26e	1.98e	0.87b	0.80d	0.79d
Location 3	2.93f	1.83c	1.40c	0.84d	0.70d
Location 4	1.91d	1.81c	0.84b	0.56b	0.49b
Location 5	1.40c	1.11d	1.40c	0.70c	0.56c
Location 6	1.05b	0.77b	0.55a	0.56b	0.44b

Mean in the same column followed by different letters in superscript are significantly different at the 5% level using Least Significant Difference (LSD)

From table 34, Cr reported different letter across the column with implication that Cr is significantly different at ($p < 0.05$) as depicted in table 33. The column 0-15 soil depth reported different letters for Cr with indication of statistical significance at ($p < 0.05$). Location 1, location 2, location 3, location 4, location 5 and location 6 have different letters with implication of significant difference among the locations and no similarities in concentration. Column 15-30 reported different letters for Cr with implications of statistical significance at ($p < 0.05$). Location 1, location 2, location 5 and location 6 have different letters which reveals significance difference among the location. Location 3 and location 4 have same letter with implication of similarities in Cr content. Column 30-45 reported different letters for Cr with indication of significance difference at ($p < 0.05$). Location 1 and location 6 have same letter with indication of similarities in concentration. Location 2 and location 4 have same letter with indication of similarities in content. Location 3 and location 5 have same letter which indicate similarities in content of Cr. Both location 3 and location 5 is significantly different from both location 1 and 6 with location 2 and 4. Column 45-60 reported different letters for Cr with implication of significant difference at ($p < 0.05$). Location 2 and location 3, reported same letter which indicates similar Cr content among the locations. Location 4 and location 6 reported same letter with indication of no significant difference. Location 1

and location 5 reported different letters implying a significant difference exist in both locations. Column 60-75 reported different letters for Cr with implication of significant difference among the locations at ($p < 0.05$). Location 2 and location 3 have same letter with implications of similarities in Cr content among both locations. Location 1, location 4, Location 5 and location 6 reported different letters with indication of significant difference among the Cr content.

From table 34, the highest mean content of Cr (2.26mg/kg) in the top soil layer among the treated soil with sludge was observed in location 2, while the lowest top soil layer mean content of Cr (1.05mg/kg) was observed in (location 6). For the bottom layer soil of the treated soils, the highest Cr content (0.79mg/kg) was observed in location 2 and the lowest bottom layer soil (0.44mg/kg) was observed in location 6. A decrease in Cr content down the soil depth was observed across the locations. The background soil (location 1) had the lowest mean content of Cr across all soil depth. This could be as a result of the soil parent material with lesser Cr. (Yadav et al., 2017; Zinn et al., 2020) reported that soil parent material and soil depth control Cr concentrations in soil. The Cr content in this case study soils were below the permissible limits of EU standard (180mg/kg), US standard (400mg/kg) and the UK standard (6.4mg/kg) according to (Ediene & Umoetok, 2017). The anaerobic digested POME of (Khairuddin, et al., 2016) reported (27.86 + 0.55ppm) content which is quite high compare to the value reported by (Osman et al., 2020). However, the Cr content in soil can be increased via the content in the organic treatment (Wang et al., 2022). Chromium in soil can exist in various oxidation state ranging from 0 to VI with Cr(III) and Cr(VI) being the most common (Prasad, et al., 2021). The solubility and mobility of Cr in soil is dependent on the soil properties and its chemical form with the hexavalent form Cr(VI) more mobile and soluble compare to the trivalent form Cr(III) which is insoluble and always bound to organic matter (Prasad, et al., 2021). High content of Cr(VI) in POME could result to contamination of the bottom soil layer and ground water through leaching. (Xu, et al., 2020) reported that the proportion of exchangeable Cr(VI) in soil increase with acidity while Cr(III) increase with increase alkalinity. Organic matter content of POME is high (Izah et al., 2016). Higher organic matter content can enhanced Cr retention reducing its mobility in soil.

Table 35: Analysis of variance for arsenic

	Depth	Sum of Squares	df	Mean Square	F	Sig.
0-15	Between Groups	.011	5	.002	5.891	.006
	Within Groups	.004	12	.000		
	Total	.015	17			
15-30	Between Groups	.610	5	.122	71.120	.000
	Within Groups	.021	12	.002		
	Total	.631	17			
30-45	Between Groups	.278	5	.056	1.000	.458
	Within Groups	.667	12	.056		
	Total	.944	17			
45-60	Between Groups	.000	5	.000	.	.
	Within Groups	.000	12	.000		
	Total	.000	17			
60-75	Between Groups	.000	5	.000	.	.
	Within Groups	.000	12	.000		
	Total	.000	17			

Table 36: Arsenic (As) mean concentration (mg/kg) across location per depth

Location	Depth(cm)				
	0-15	15-30	30-45	45-60	60-75
Location 1(Ctrl)	0.00a	0.00a	0.00a	0.00a	0.00a
Location 2	0.05c	0.01a	0.00a	0.00a	0.00a
Location 3	0.06d	0.01a	0.00a	0.00a	0.00a
Location 4	0.02b	0.01a	0.00a	0.00a	0.00a
Location 5	0.00a	0.00a	0.00a	0.00a	0.00a
Location 6	0.05c	0.05b	0.00a	0.00a	0.00a

Mean in the same column followed by different letters in superscript are significantly different at the 5% level using Least Significant Difference (LSD)

From table 36, As reported different letters for column 0-15 and column 15-30 with indication of significance difference at ($p < 0.05$) as shown in table 35. Column 30-45, column 45-60 and column 60-75 reported same letter among the locations in each column with implications of similarities in As content among the locations in these columns. Column 0-15 soil depth reported different letters for As with indications of significant at ($p < 0.05$). Location 1 and location 5 have same letters with implications of similarities in As content in both locations. Location 2 and location 6 also have same letter with implication of similarities in both locations. Location 3 and location 4 reported different letters with implications of significant difference in As content. Column 15-30 soil depth reported different letters for As with indications of significant difference at ($p < 0.05$). Location 1 to location 5 have same letter with indication of similarities in As content among the locations. Location 6 have different letter from the other locations which indicates significant difference from location 1 to location 5.

The As table 36 showed that As was not detected in the background (location 1) soil. Also, As was scarcely detected in the locations of the experimented soils except in the top layer soil where a very low content ranging from 0.02-0.06mg/kg was observed. The case study of (Okoye et al., 2022) carried out in Niger Delta (southern) Nigeria major cities like Choba, Eleme, Khana, Transamadi, Uyo, Yenogoa, with too low or no content of As confirmed the possibility of the soil parent material of this region or area is deficient or naturally low in As content. POME is highly organic and could potentially increase the organic matter content in the soil (Ohimain et al., 2012). (Pothier, et al., 2020) reported that organic matter controls the bioavailability of As in soil as Arsenic binds to the negatively charged organic matter through adsorption or precipitation process. This static force can limit the mobility of As in the POME treated soil making the detection to be difficult.

Table 37: Analysis of variance for mercury

		Sum of				
		Squares	df	Mean Square	F	Sig.
A	Between Groups	.000	5	.000	2.700	.074
	Within Groups	.000	12	.000		
	Total	.001	17			
B	Between Groups	.000	5	.000	.	.
	Within Groups	.000	12	.000		
	Total	.000	17			
C	Between Groups	.278	5	.056	1.000	.458
	Within Groups	.667	12	.056		
	Total	.944	17			
D	Between Groups	.000	5	.000	.	.
	Within Groups	.000	12	.000		
	Total	.000	17			
E	Between Groups	.000	5	.000	.	.
	Within Groups	.000	12	.000		
	Total	.000	17			

Table 38: Mercury (Hg) mean concentration (mg/kg) across location per depth (cm)

Location	Depth(cm)				
	0-15	15-30	30-45	45-60	60-75
Location 1(Ctrl)	0.00a	0.00a	0.00a	0.00a	0.00a
Location 2	0.01a	0.00a	0.00a	0.00a	0.00a
Location 3	0.01a	0.00a	0.00a	0.00a	0.00a
Location 4	0.00a	0.00a	0.00a	0.00a	0.00a
Location 5	0.00a	0.00a	0.00a	0.00a	0.00a
Location 6	0.01a	0.00a	0.00a	0.00a	0.00a

Mean in the same column followed by different letters in superscript are significantly different at the 5% level using Least Significant Difference (LSD)

From table 38, Hg reported same letters for all columns from 0-15 to 60-75 with implications of no significant difference among the locations in each column. This implies that Hg content across the location is similar.

Hg was undetected in almost all the locations across depth in the soil except in location 2, location 3 and location 6 where 0.01mg/kg were observed in the top layer soil of 0-15cm. However, where mercury was detected, the level obtained was higher than the United state Environmental Protection Agency (USEPA) residential soil screening level of 0.0023mg/kg (Udokoya, et al., 2021). Hg availability in Nigeria soil is mainly due to anthropogenic activity such as iron and steel mine, cement, non-ferrous metal smelting with gold mining contributing the highest Hg to the soil (Pavithra et al., 2022). This was observed from the case study of (Odukoya et al., 2021) where Hg in gold mine site in Niger state, North-central, Nigeria with range (0.19-20.99mg/kg) was far beyond the Hg in agricultural site (0.02-5.57) in the same locality. The case study done by (Okoye et al., 2022) in some major city in Niger Delta Southern region like Choba, Eleme, Khana, Transamadi, Uyo, Yenogoa, with Hg content range of (0.0003-0.01mg/kg) showed that Hg content in the Southern region of no gold mine is almost insignificant. This showed that Southern Nigeria may have naturally low level of Hg in soil due to environmental conditions. The Hg content of POME are generally low and below detectable limits. (Khairuddin, et al., 2016), (Osman et al., 2020), (Ohimain et al., 2012) reported no content of Hg in the POME heavy metal analysis.

6.1 Essential heavy metal

Heavy metals can be either essential or non essential depending on its requirement whether for plant or animals. The essential heavy metal such as Cu, Mn, Zn, Ni, Fe are often called trace elements or micro elements due to their low concentration requirement in growth and development as well as stress resistant and biosynthesis (Ali et al., 2019). However, essential heavy metal can be toxic to plant and human life when taken in

insufficient or excess amount. Fig 11-16 show the comparison of the mean concentration of essential heavy metal (Cu, Mn, Zn, Ni) in location 1 to location 6.

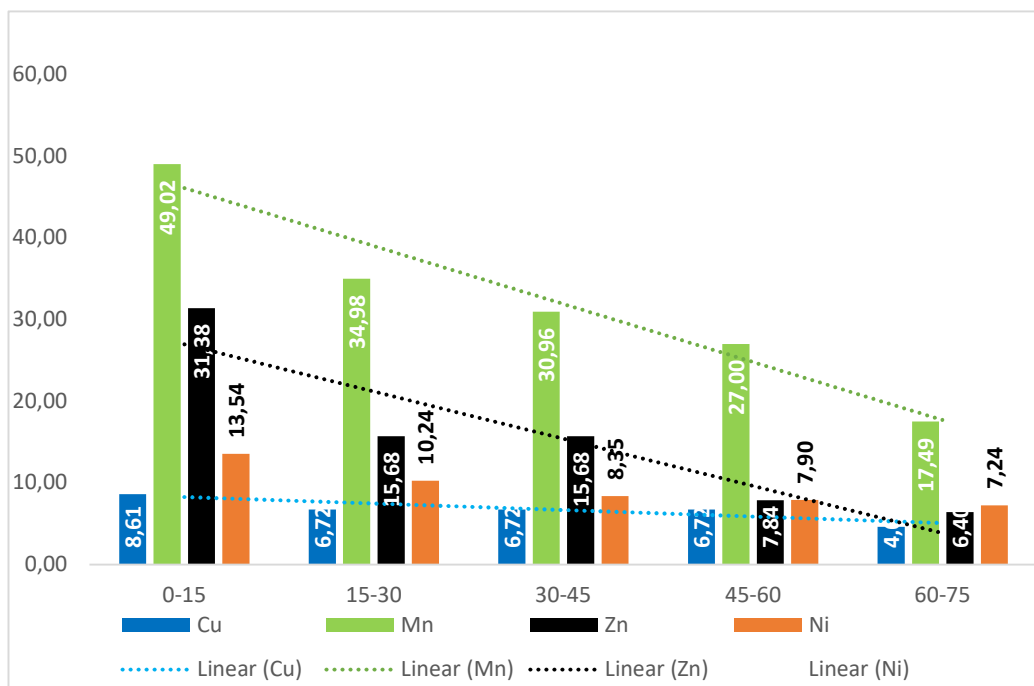


Figure 11: Location 1 (control) essential heavy metal

From the figure 11 above in location 1 (control soil), the content of Mn was the highest in the background soil with implication that the soil in this location is sufficient in Mn than Cu, Zn and Ni. (Igwe et al., 2021) reported that Mn is naturally occurring metal which is abundant in soil. From the Mn content, there could be weathering process that might have release Mn into the soil in this locations. The Mn content in the control (location 1) was observed to be higher than some treated soil location such as Location 6, location 5, location 4 location 3 in some depth. This implied that the POME treatment had less or no effect on Mn in the soil. The Zn content was also high implying that Zn is naturally abundant in the soil in this location with implication of less effect of POME treatment in the soils. Cu and Ni content in the background soil was lower than the content in the treated soil which implied that the anthropogenic activity of soil treatment with POME contributed Cu and Ni to the soil effectively. Exception was observed in location 6 of Ni where similar content of Ni was obtained. A downward trend or decrease of the essential metals was observed from the top soil to the bottom soil. These trend could be as a result of the physico-chemical properties of the soil.

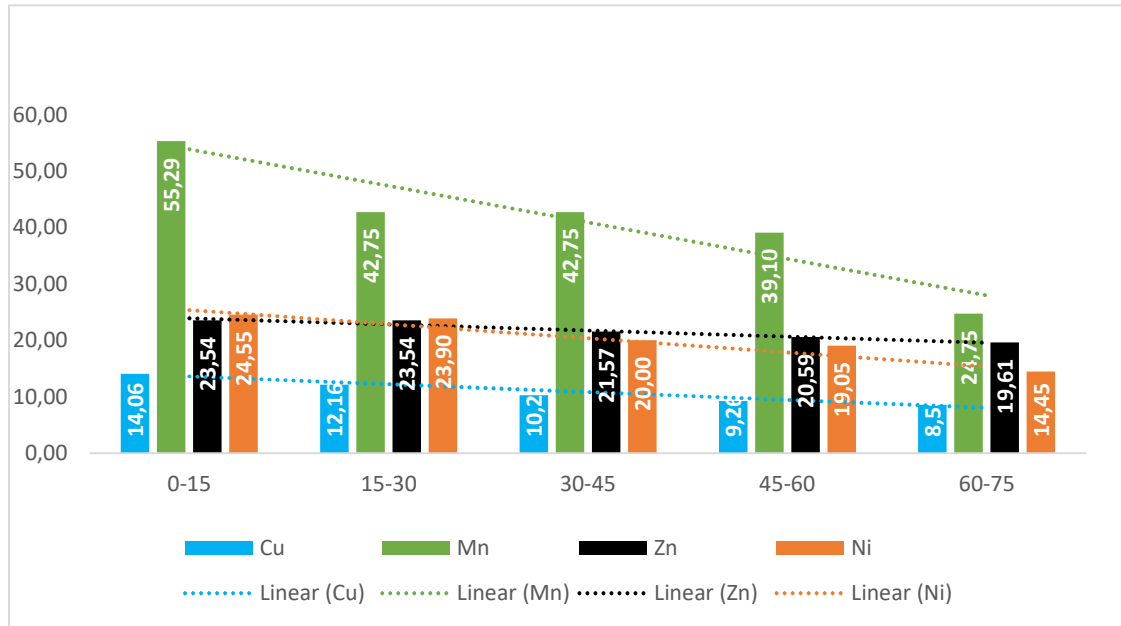


Figure 12: Location 2 Essential heavy metals (Cu, Mn, Zn, Ni) across depth

From the figure 12 above in location 2, the content of Mn was the highest in the soil with a decrease from the top soil to the bottom soil. Moreover, Mn in this location was highest among the other treated locations. The implication of this result is that the soil in this location have sufficient Mn content which could be due to the soil parent material of the region or area. Mn content was the same in depth (15-30cm) and (30-45cm). Zn and Ni were in almost the same range except in the bottom soil where Zn was slightly higher than Ni. Cu content was the lowest in the soil across the depth from the top soil to the bottom among the essential element. The decrease trend from top soil could be due to the effect of the anthropogenic effect of the POME treatment in the soil. (Nwachukwu et al., 2018) reported that POME treatment in soil increases the organic matter content with the trend of decrease from the top soil of application to the bottom soil. (Oyinlola & Chude, 2010; Orhue et al., 2015) reported decrease trend of heavy metal from top soil to bottom soil could be attributed to the organic matter downward trend from the top soil to the bottom soil in the same region.

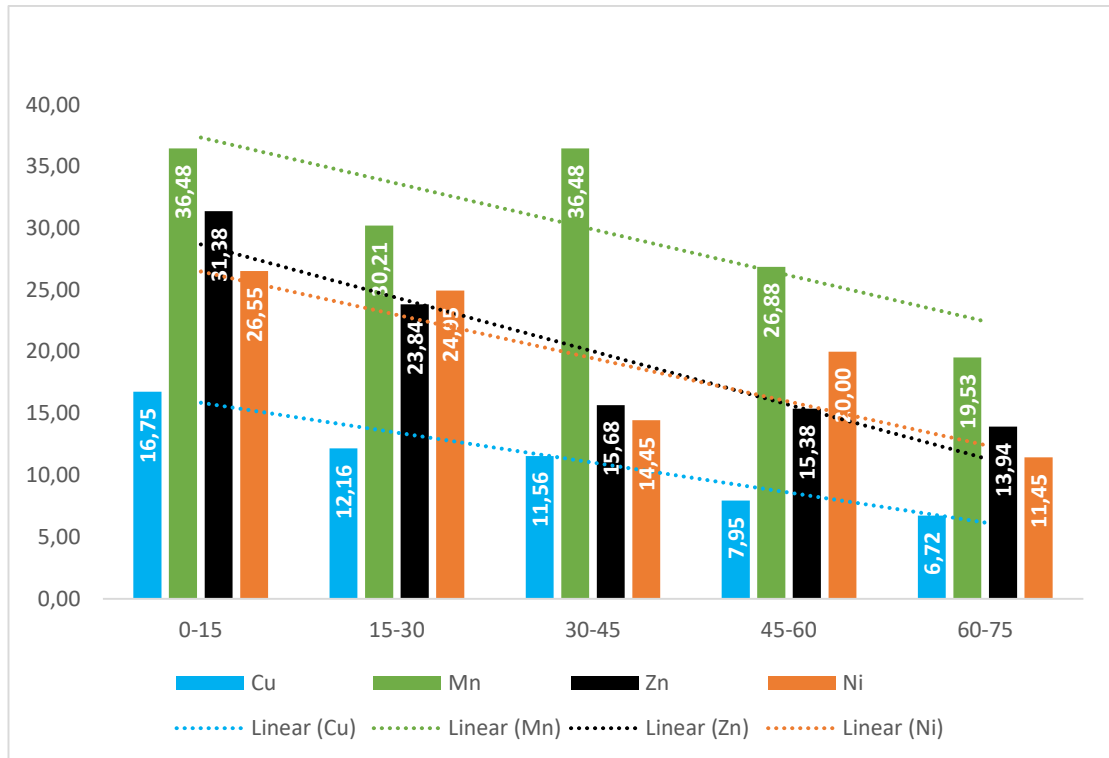


Figure 13: Location 3 Essential heavy metals (Cu, Mn, Zn, Ni)

From the figure 13 above in location 3, the content of Mn was the highest in the soil with a decrease from the top soil to the bottom soil. However, Mn in the sub layer soil (15-30cm) was lower than the mid layer soil of (30-45cm). The implication of this result is that the soil in this location have sufficient Mn content. Zn and Ni ranges were similar in content compared with Cu and Mn. Cu content in the location was the lowest across all depth. A decrease trend in content was observed in all metals from the top to the bottom soil except in some instances in Mn where (30-45cm) content was more than (15-30cm) and in Ni where (45-60cm) soil was more than the (30-45cm). Studies have shown that the decrease trend of heavy metal from top soil to bottom could be due to leaching effect of the elements from higher to lower concentration via ferti-irrigation with POME.

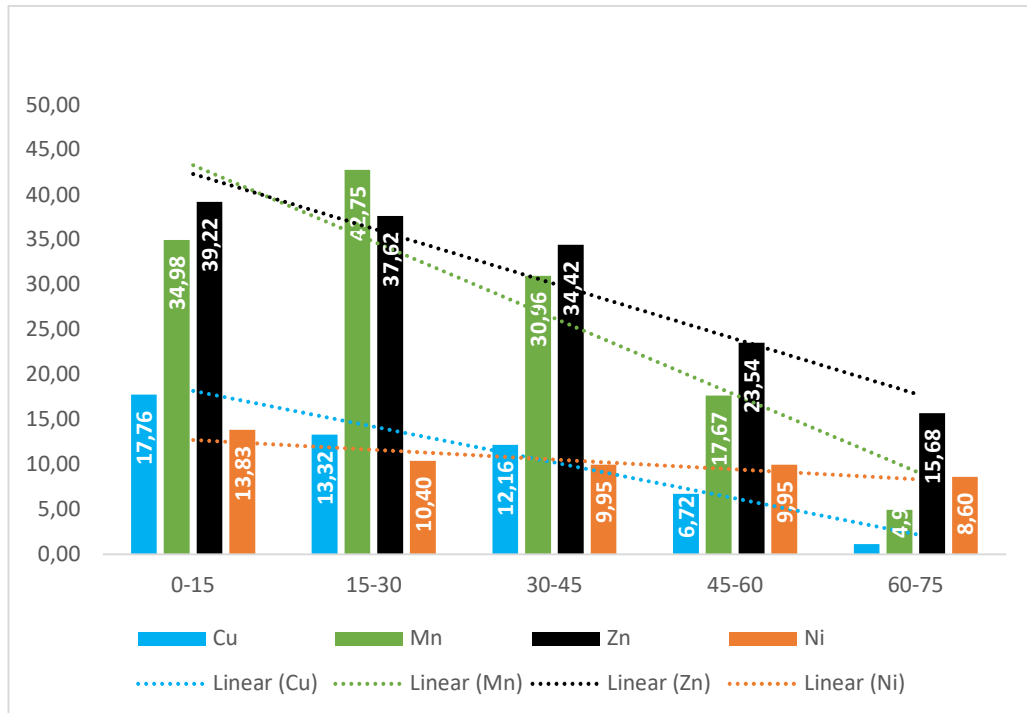


Figure 14: Location 4 essential heavy metal

From the figure 14 above in location 4, the content of Zn was higher in the top soil compare to the other locations. The Zn content in soils was higher in location 4 compare to the other location. Cu content was also observed to be higher in location 4, while Ni content was less than the content of location 2 and location 3. A downward trend of the metals contents was observed from the top soil to the bottom except in Mn where the sub layer soil (15-30cm) was higher than the top layer (0-15cm). The downward trend in concentration could be due to dispersion and dilution of the metals as POME run through the soil profile resulting in lower concentration at the bottom depth.

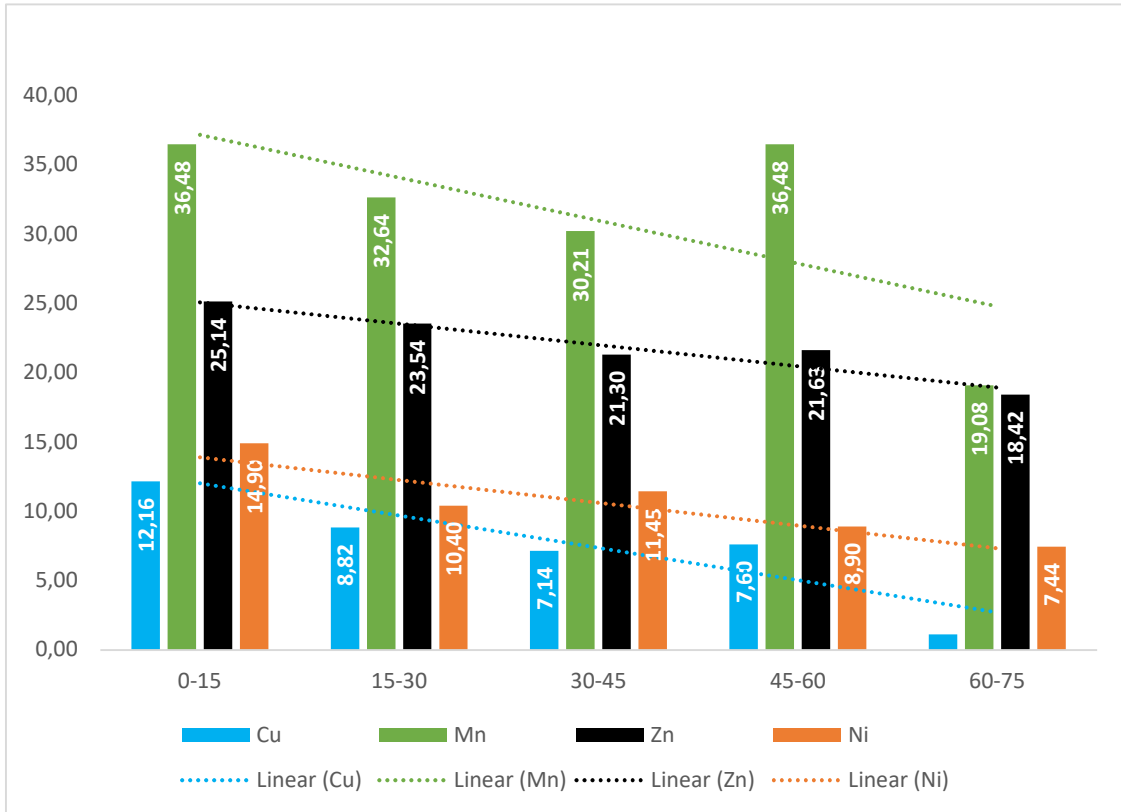


Figure 15: Location 5 Essential heavy metal

From the figure 15 above in location 5, All the metal (Cu, Mn, Zn, Ni) showed a decrease in content from the top soil to bottom with an exception of Mn having same content of (36.48mg/kg) in the (0-15cm) and (45-60cm), Zn content in 45-60cm was a bit higher than the (30-45cm) depth, Ni content was higher in (30-45cm) than the (15-30cm) and Cu content was slightly higher in (45-60cm) than the (30-45cm). The downward content trend in the metals could be due to same effect as earlier discussed.

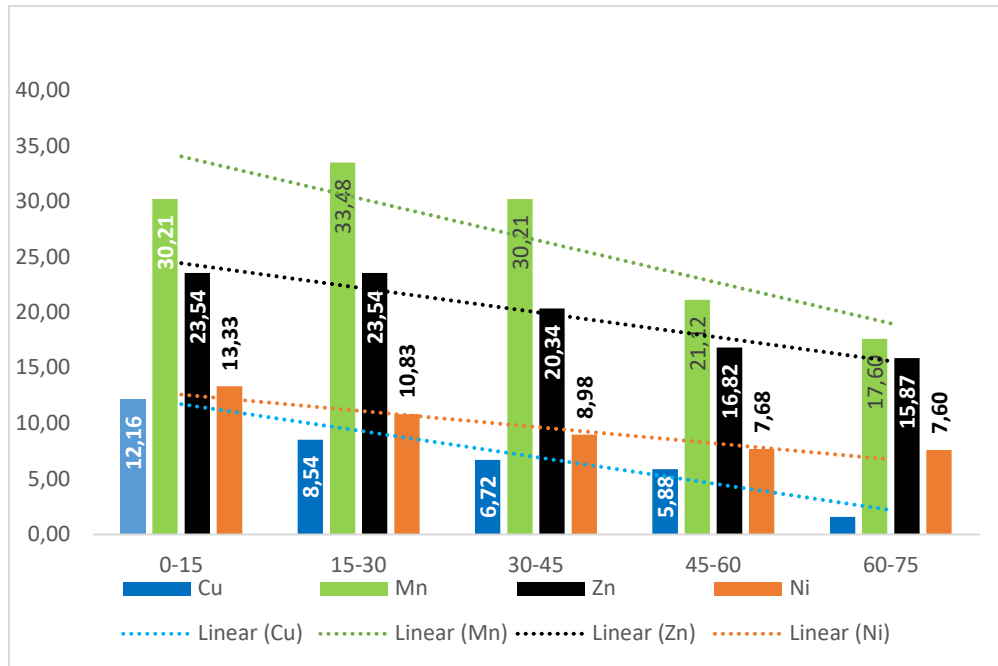


Figure 16: Location 6 essential heavy metal

From the figure 16 above in location 6, the content of Mn was the highest in the soil followed by Zn. All metals showed decrease in content from top soil to bottom soil except in Mn where the content of the sub layer of (15-30cm) was higher than the top layer (0-15cm). Cu content in the soil location was lowest among the essential heavy metal with a slight difference below the Ni concentrations. The downward trend in content from top soil to bottom soil could be due to the soil location properties such as pH, CEC, organic matter which determine the mobility and solubility in the soil as discussed earlier.

6.2 Non-essential heavy metal

Non-essential heavy metal (Cd, Pb, Hg, As, Cr) are also known as toxic metal due to their toxicity to plant and animal. These sets of metals play no functional biological role in organism's life. At low level, they can be tolerated and harmful at elevated concentrations (Ali et al., 2019).

The essential heavy metals (Cu, Mn, Zn and Ni) contents in soil in this case study were observed to be more significant in quantity than the non-essential metal. The reason could be that the parent material in the soil of this locations are more concentrated in essential metal than the non-essential metal. Also, the anthropogenic activity of ferti-irrigation of the plantation with anaerobic treated palm oil mill effluent contributed insignificant amount of these non-essential toxic elements to the soils. POME contain more of these essential metals than the non-essential from the characteristics of POME.

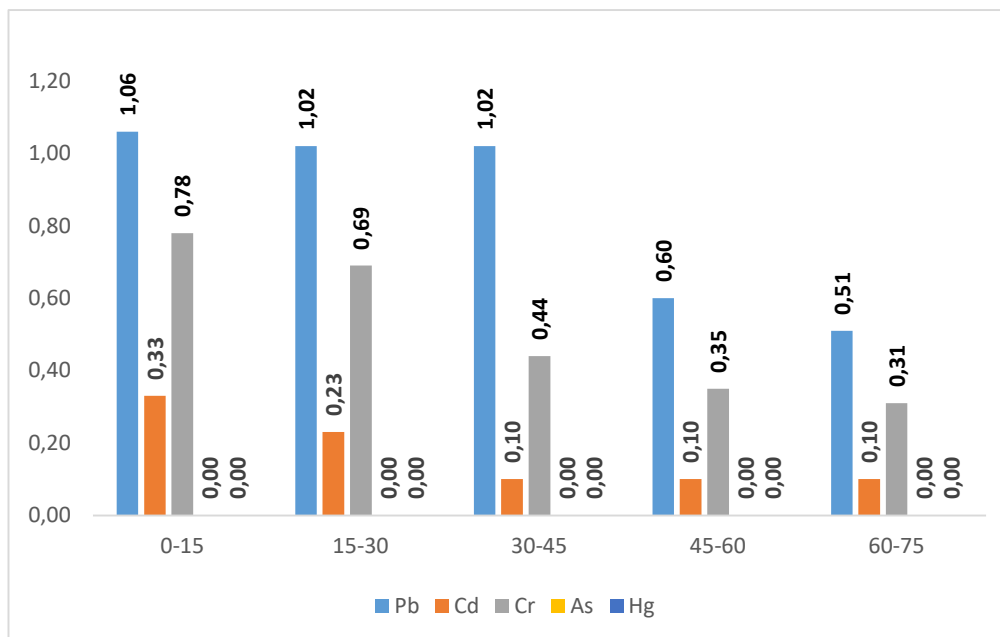


Figure 17: Non-essential heavy metal control soil (location 1)

From the figure 17 above in location 1 (background), Pb, Cr and Cd were observed in the soil. While Pb content was highest in the topsoil layer followed by Cr, Cr content was highest in the subsoil. The content of both Pb and Cr was in the same range in the bottom soil. Cd content was low across the soil depth with decreasing trend from the topsoil to the bottom soil. As and Hg were undetected in the soil of this background location.

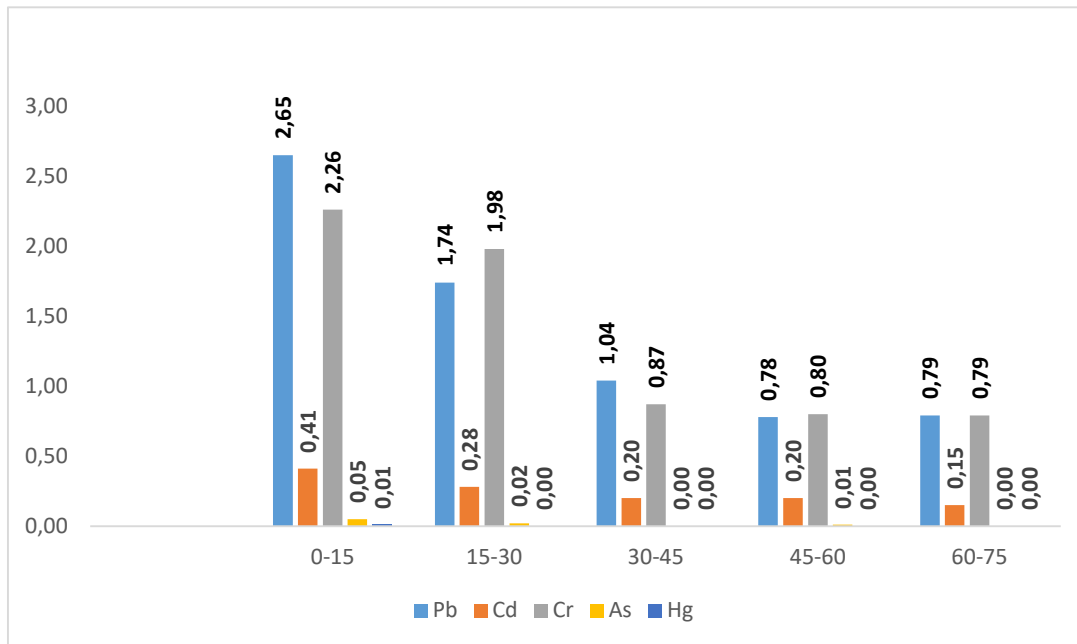


Figure 18: Non-essential heavy metal (Location 2)

From the figure 18 above in location 2, the content of Pb in the topsoil layer was higher followed by Cr. However, in the sublayer, Cr was higher than Pb. Both Pb and Cr content in the bottom soil was in the same range. The content of Cd was very low in the soil with a downward trend from top soil layer to bottom layer soil. As and Hg was very low and insignificant in cases where it was observed. As was not detected in mid layer soil 30-45cm and bottom layer soil (60-75cm). Hg was only detected to the tune of 0.01mg/kg in the top layer soil. Only Pb Cr and Cd was observed all through the soil layers from top to bottom in a decrease trend in significant amount.

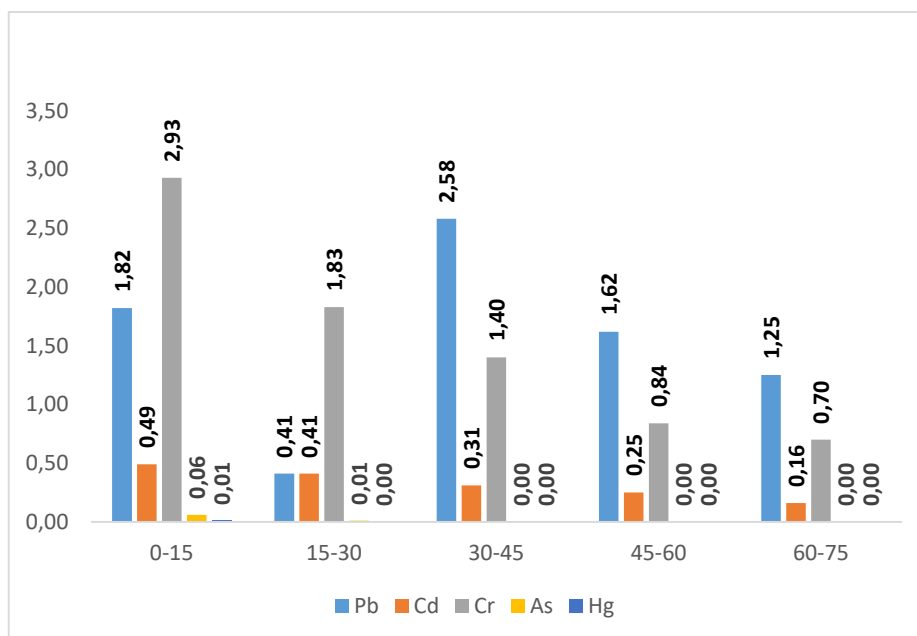


Figure 19: Non-essential heavy metal (location 3)

From the figure 19 above in location 3, Cr had the highest content in the soil followed by Pb. The content of Pb was higher across depth except in top layer soil where Cr had the highest content in the location. Cd concentration was lower in the soil in a decrease trend from top to bottom soil compare to Cr and Pb content. Cr and Pb content was observed vividly in significant amount with a decrease trend from top layer soil to the bottom layer soil. The content of As, and Hg was very low and insignificant in cases where it was observed. Cd was observed in the top layer soil of (0-15cm) and (15-30cm) with content of (0.49mg/kg) and (0.41mg/kg) respectively. As was observed in the top layers of (0-15cm) and (15-30cm) with content of (0.06mg/kg) and (0.01mg/kg) respectively. As was not detected in the mid later through to the bottom soil. Hg was only detected at a very low level (0.01mg/kg) in the top layer soil (0-15cm).

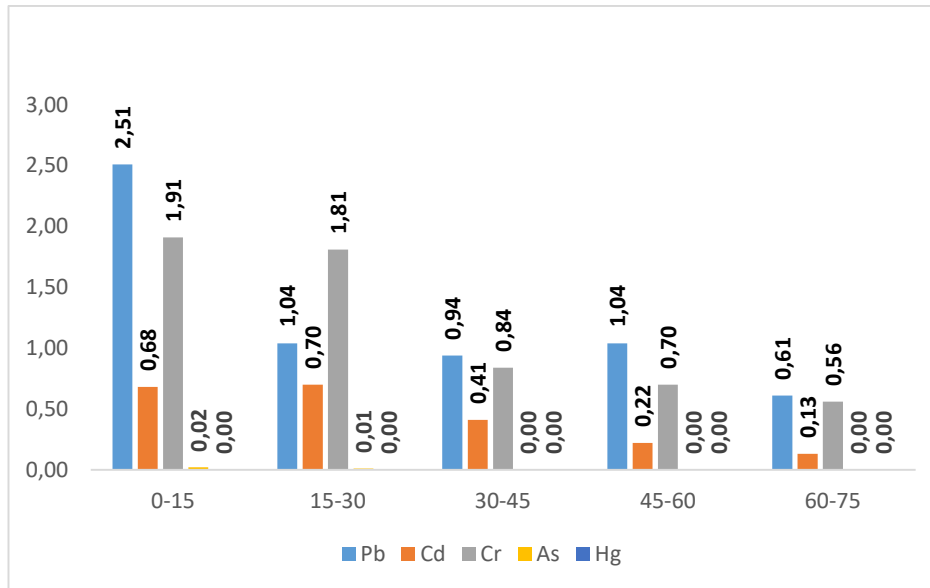


Figure 20: Non-essential heavy metal (location 4)

From the figure 20 above in location 4, Pb had the highest content in the top soil followed by Cr. However, in the sub layer soil, Cr content was higher than Pb content. Cr content in this location was low compare to that of location 2 and location 3 with a decrease trend from top soil to bottom soil. Cd content from top soil layer to mid soil layer was higher than the content of location 2 and location 3. As was only observed in the top layer of 0-15cm and 15-30cm with content of 0.02mg/kg and 0.01mg/kg respectively. As was not detected in the mid layer soil all through to the bottom layer soil. Hg was not detected in soils of location 4 across the soil depth.

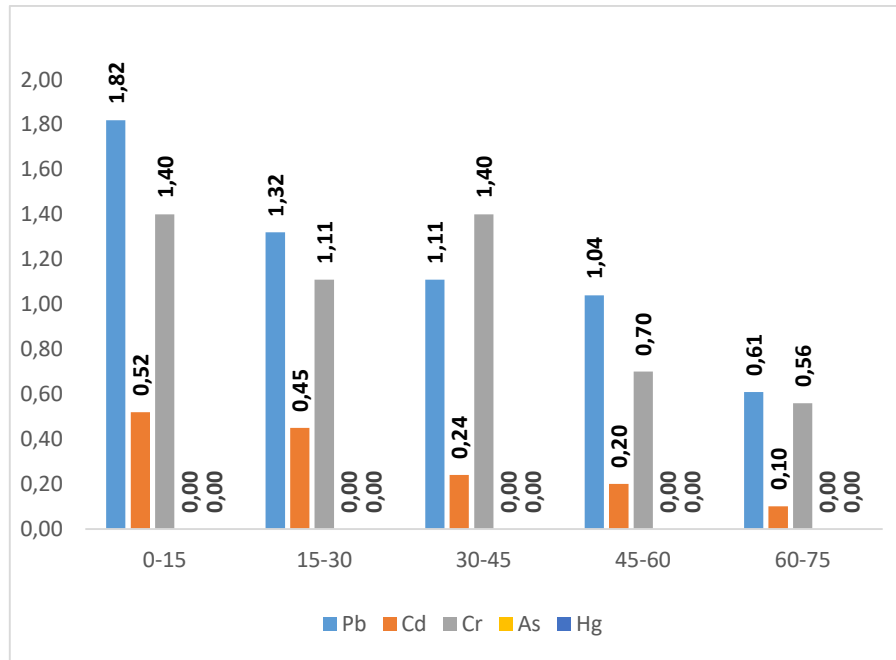


Figure 21: Non-essential heavy metal (location 5)

From the figure 21 above in location 5, Pb had the highest content in the soil followed by Cr. However, the content of Pb was lower in the mid layer than the Cr content. The content of Cr was low compare to the content in other treated locations. A decreased trend of content was observed in Pb and Cr from top soil to the bottom except in mid layer soil (30-45cm) where the Cr content was higher than the 15-30cm. Cd was detected across the soil depth with a decrease trend from top layer to bottom layer soil. As and Hg was undetected in this location across the soil depth.

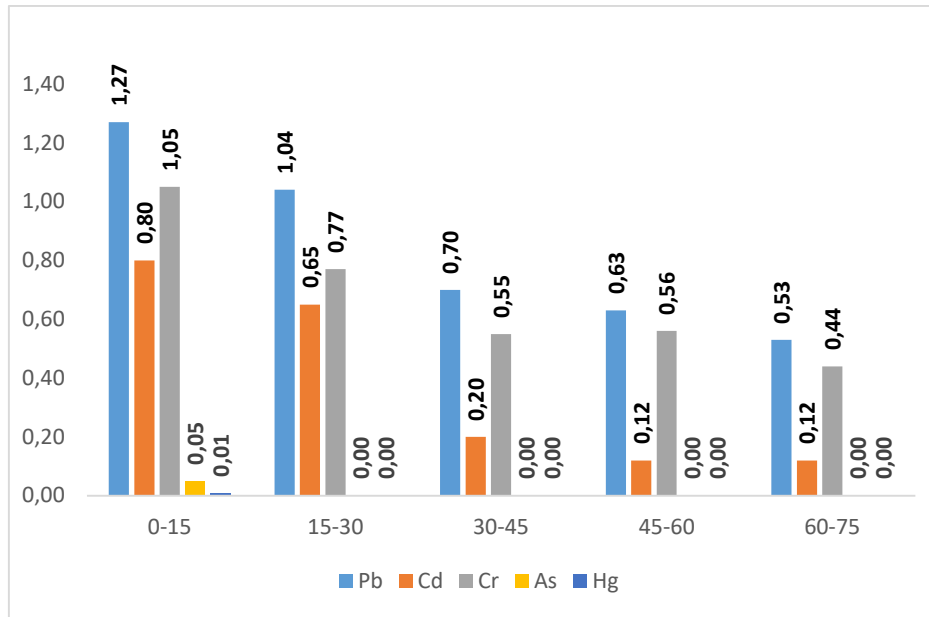


Figure 22: Non-essential heavy metal (location 6)

From the figure 22 above in location 6, Pb was highest in content across the soil depth from top soil to bottom soil layer followed by Cr. Cd was observed in the soil from the top layer soil to the bottom layer. A decrease trend was observed in Pb, Cr, and Cd from top soil layer to the bottom soil layer. As and Hg was only detected in the top layer soil in 0.05mg/kg and 0.01mg/kg respectively.

6.3 Cluster analysis

Cluster analysis was used to group the various locations according to similarities based on the distance or similarities measures. From the cluster analysis in figure 23 below, the dendrogram extracted two clusters. Cluster 1 consist of location 5, location 6, location 3 and location 4. Location 5 and location 6 bear closer similarities and location 3 and location 4 bears closer similarities. Cluster 2 consist of location 1 (control) and location 2

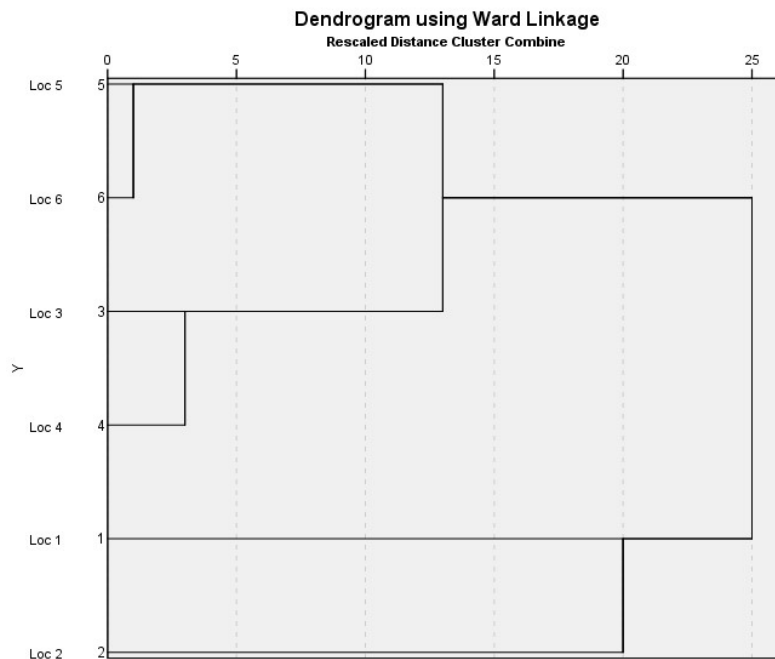


Figure 23: The Cluster analysis of Heavy Metals for 0-15cm soil depth

From the cluster analysis in figure 24 below, the dendrogram grouped the location into two clusters. Cluster 1 consist of location 1, location 6 and location 5. From the results, location 1 bear similarities with location 6 and both bear similarities with location 5. Cluster 2 consist of location 2, location 3 and location 4. Indications shows that location 2 bear similarities with location 3 and both location 2 and location 3 bear similarities with location 4.

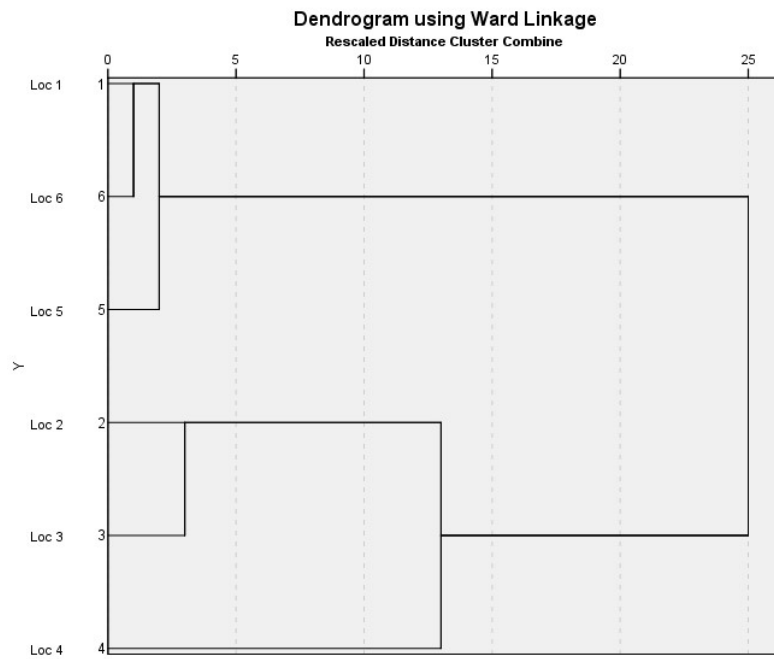


Figure 24: The Cluster analysis of Heavy Metals for 15-30cm soil depth

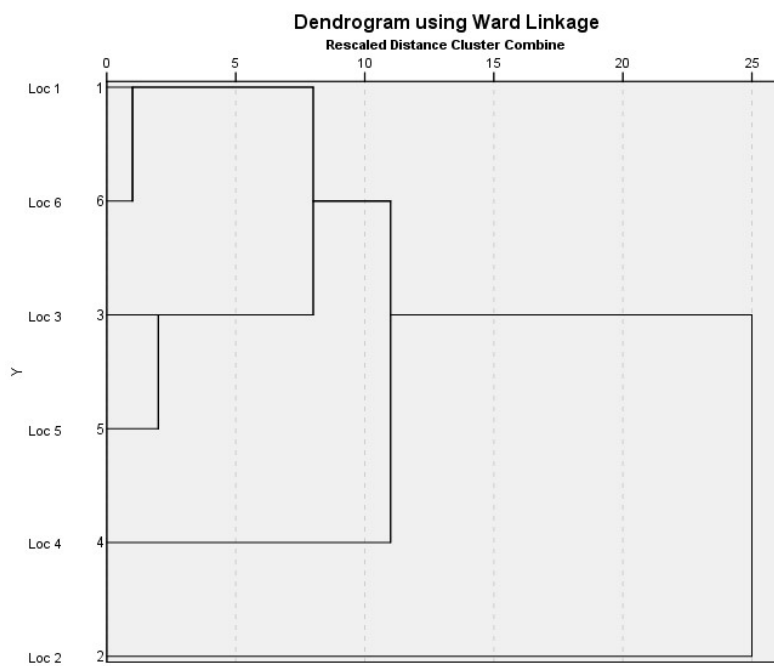


Figure 25: The Cluster analysis of Heavy Metals for 30-45cm soil depth

From the dendrogram, in fig 25 above, two clusters were extracted. Cluster 1 consist of location 1 (control), location 6, location 3 location 5 and location 4. At the lowest level of grouping, location 1 and location 6 were grouped indicating that the heavy metals from these two locations were similar. Similarly, location 3 and location 5 were grouped indicating similarities between the two location. The two groups were linked together at higher level of groupings. This shows that some heavy metals changes between the locations, while some did not exhibit any significant changes. However, these two groups were further linked to location 4, indicating similarities within the group. Cluster 2 consist of location 2. This separation of this location from other locations shows that the heavy metals in this location show some differences with heavy metals in cluster 1 at this depth.

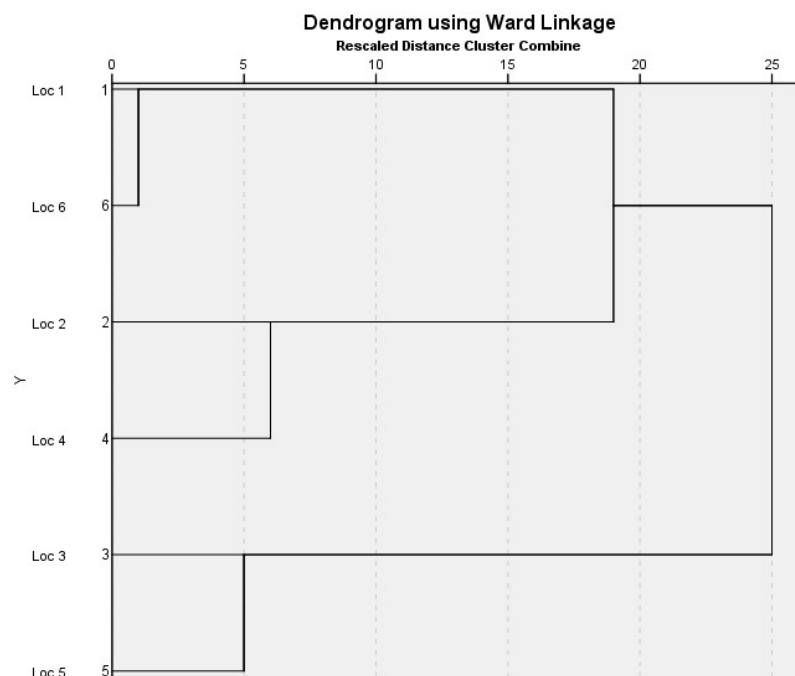


Figure 26: The Cluster analysis of Heavy Metals for 45-60cm soil depth

Two clusters were extracted from the dendrogram in figure 26 above. Cluster 1 consist of location 1, location 6, location 2 and location 4. At the lowest level of groupings, location 1 (control) and location 6 were grouped indicating that the heavy metals from these two location bear similarities. Also location 2 and location 4 were grouped indicating similarities of heavy metals within the two location. At a higher level of grouping, these two groups were linked as one showing similarities of heavy metals

within cluster 1. Cluster 2 consist of location 3 and location 5. This results show that close similarity exists within the two locations

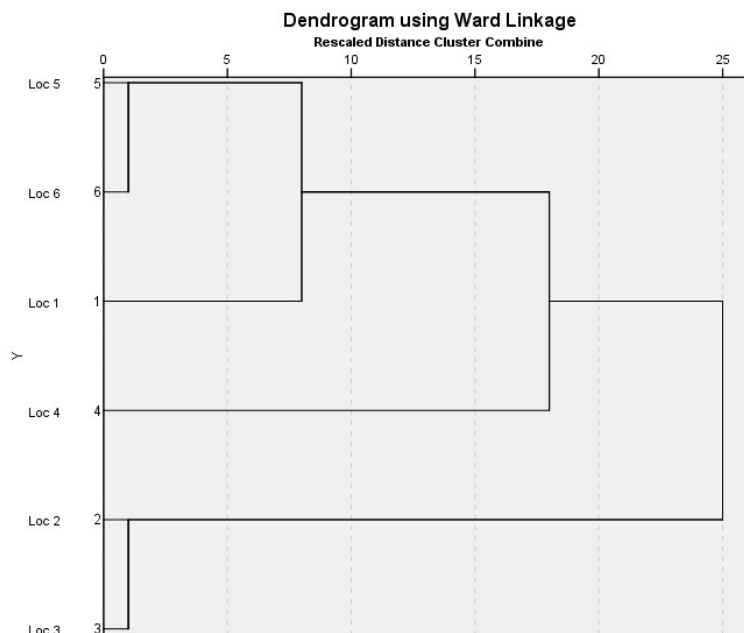


Figure 27: The Cluster analysis of Heavy Metals for 60-75cm soil depth

From figure 27 above, two clusters were observed in the dendrogram. Cluster 1 consist of location 5, location 6, location 1 (control), and location 4. Location 5 and location 6 have the closest similarities in terms of heavy metals. This was further linked to location 1 (control) and location 4 indicating a similarity in heavy metals among these locations. Cluster 2 consist of location 2 and location 3. This indicates that even though some differences were observed with the different groupings, some elements may exhibit similarities among the six locations.

6.4 Contamination factor (CF)

Contamination factor show the level at which the soil is contaminated with any heavy metal (Benarabi et al., 2021). Contamination factor is an indication of the addition of contaminant in the experimented soil medium in comparison to the background or control soil (Ogeleka et al., 2018). The level of the anthropogenic contamination of the soil via the application of treated palm oil mill effluent are shown in the elemental

contamination factor in the table below. The mean concentration of each analysed heavy metal across the five sample soil depths were obtained for the treated soils. The contamination factor was obtained using the equation 4 in the chapter 5 above.

Table 39: Contamination factor of Cu

Cu	Depth(cm)				
	0-15	15-30	30-45	45-60	60-75
Location 2	1.6	1.8	1.5	1.3	1.9
Location 3	1.9	1.8	1.7	1.1	1.5
Location 4	2.1	2.0	1.8	1.0	0.2
Location 5	1.4	1.3	1.1	1.1	0.3
Location 6	1.4	1.3	1.0	0.9	0.3
AVERAGE	1.7	1.6	1.4	1.1	0.8

Table 39 shows the results of the contamination factor of Cu in the five-sample soil depth across the 5 locations. From the table, it was observed that the CF was in descending order from the top soil to the bottom soil. That is (0-15cm) > (15-30cm) > (30-45cm) > (45-60cm) > (60-75cm). This downward CF trend could be as result of leaching with percolating rainwater or decrease organic matter content of the soil with the POME application (Nwachukwu et al., 2018). The CF for the bottom soil layer (60-75cm) of Location 4, location 5 and location 6 shows implication of Cu contamination at low level (CF < 1). The CF of Cu across the location falls mostly in the range of moderate contamination (1 < CF < 3) as depicted in table 18 above with exception in depth 45-60cm of location 6. The result from the background soil value and treated soil values shows that the moderate contamination of the soil could be as a result of the Cu content in the soil parent material and the POME ferti-irrigation of the soils. The results implication shows there is influence of POME in the soils. This influential effect could increase in long term application of this effluent due to the bio-accumulation property of heavy metal in soils.

Table 40: Contamination factor of Mn

Mn	Depth(cm)				
	0-15	15-30	30-45	45-60	60-75
Location 2	1.1	1.4	1.4	1.1	1.4
Location 3	0.7	0.9	1.2	1.0	1.1
Location 4	0.7	1.4	1.0	0.7	0.3
Location 5	0.7	0.9	1.0	1.4	1.1
Location 6	0.6	1.0	1.0	0.8	1.0
AVERAGE	0.8	1.1	1.1	1.0	0.9

Table 40 shows the results of the contamination factor of Mn in the five sample soil depth across the 5 locations. The CF for the top soil layer (0-15cm) of Location 3 to location 6 shows implication of heavy metal contamination at low CF. The bottom soil layer (60-75cm), shows implication of heavy metal contamination at the low contamination factor category ($CF < 1$) at location 3. The CF for the other soil depth falls between the moderate contamination range ($1 < CF < 3$) as depicted in table 18 above. The lower CF values observed in Mn could be due to the stable nature of Mn in the earth crust. (Benarabi et al., 2021) reported similar CF of Mn attesting to this fact. The higher values of Mn in the background soil implied that the soil parent material in the region or locality contain higher amount of Mn. The significant difference in Mn content between the control location and the treated soil location implied the introduction of Mn to the soil via POME application.

Table 41: Contamination factor of Zn

Zn	Depth(cm)				
	0-15	15-30	30-45	45-60	60-75
Location 2	0.8	1.5	1.4	2.6	3.0
Location 3	1.0	1.5	1.0	2.0	3.0
Location 4	1.2	2.4	2.2	3.0	2.2
Location 5	0.8	1.5	1.4	2.8	2.8
Location 6	0.8	1.5	1.3	2.1	2.5
AVERAGE	0.9	1.7	1.5	2.5	2.7

The contamination factor of Zn in the five sample soil depth are shown in table 41 above. The CF for the top soil layer (0-15cm) at location 2, location 5 and location 6 shows implication of Zn contamination at low level ($CF < 1$). The CF for the other soil depths fall between the moderate contamination range ($1 < CF < 3$) as depicted in the table 18 above. The CF of the soil depth was in ascending order from top soil to the bottom soil. The content of Zn in the background soil implied that Zn is naturally present in the soil of this region. The significant difference between the Zn content in the background soil and the treated soil implied the contamination of the soil with anthropogenic activities of POME treatment. Long term application of the POME treatment could result to higher contamination factor due to the persistent and bioaccumulation property of this heavy metal.

Table 42: Pb contamination factor

Pb	Depth(cm)				
	0-15	15-30	30-45	45-60	60-75
Location 2	2.5	1.7	1.0	1.3	1.5
Location 3	1.7	0.40	2.4	2.7	2.4
Location 4	2.3	1.0	0.9	1.1	1.1
Location 5	1.7	1.2	1.0	1.7	1.2
Location 6	1.1	1.0	0.7	1.0	1.0
AVERAGE	1.8	1.1	1.2	1.6	1.4

The contamination factor of Pb in the five sample soil depth across the 5 locations are shown in table 42 above. The CF of the 15-30cm soil depth at location 3 and 30-45cm soil depth at location 6 shows implication of Pb contamination at low level (CF < 1). The CF for the other depths and location falls between the moderate contamination range of (1 < CF < 3) as depicted in table 18 above. There was no consistency in ascending or descending order of the CF of Pb across soil depths. This lack of consistency in CF across depth of Pb could be attributed to its low mobility in the soil according to (Igwe et al., 2021). Moreover, Pb CF could vary spatially due to variations in the anthropogenic POME applications. The significant difference between the background soil and the treated soil implied that the contamination of Pb in the soil could be as a result of the POME treatment. In addition, contamination of Pb in the soil could be from exhaust fumes from automobile and machines engines used in the plantation (Ogeleka et al., 2018).

Table 43: Ni contamination factor

Ni	Depth(cm)				
	0-15	15-30	30-45	45-60	60-75
Location 2	1.8	2.3	2.4	2.4	1.9
Location 3	1.9	2.4	1.7	2.5	1.5
Location 4	1.0	1.0	1.2	1.3	1.1
Location 5	1.1	1.0	1.3	1.1	1.0
Location 6	0.9	1.0	1.1	0.9	1.0
AVERAGE	1.3	1.5	1.5	1.6	1.3

Table 43 shows the results of the contamination factor of Ni in the five-sample soil depth across the locations. From the table, it was observed the CF was not consistent with increase or decrease order from the top soil to the bottom soil. The CF of Ni for the top soil layer (0-15cm) and the (45-60cm) both at location 6 shows implication of Ni contamination at low level ($CF < 1$). The CF for the other soil depth falls between the moderate contamination range ($1 < CF < 3$) as depicted in table 18 above. The significant difference between the Ni content in the background level and the POME treated soil revealed soil contamination. The non-consistence order of increase or decrease of Ni CF could be due to Ni natural occurrence in the region and the soil properties such as pH, CEC and the organic matter content which determine the mobility and stability of Ni in the soil (Shakery et al., 2010). Moreover, sandy feralitic nature of soil area could vary in soil layers with distinct soil properties with implication of Ni uneven distribution (Ogeleka et al., 2018). The long term application of POME treatment could increase the CF of the soil due to the bioaccumulation property of Ni as heavy metal.

Table 44: Cd contamination factor

Cd	Depth(cm)				
	0-15	15-30	30-45	45-60	60-75
Location 2	1.2	1.2	2.0	2.0	1.5
Location 3	1.4	1.7	3.1	2.5	1.6
Location 4	2.0	3.0	4.1	2.0	1.3
Location 5	1.5	1.9	2.4	2.8	1.0
Location 6	2.4	2.8	2.0	1.2	1.2
AVERAGE	1.7	2.1	2.7	2.1	1.3

The CF of Cd was observed in the five soil depth from (0-15cm) to (60-75cm) in an uneven distribution pattern in table 44. This could be due to the soil pH across the soil depth as Cd mobility is influenced by the pH (Igwe et al., 2021). The CF in the bottom soil (60-75cm) was lower than the CF in other depth as observed across the location and the average value. The CF of Cd in all the soil depth from (0-15cm) to (60-75cm), shows implication of Cd contamination at moderate level ($1 < CF < 3$). Cd CF at depth 30-45cm in location 3 and 4 indicated considerable level of contamination ($3 < CF < 6$). This Uneven pattern of distribution was undetected in the background soil which implied that the low contaminations in these soils resulted from the POME applications.

Table 45:Cr contamination factor

Cr	Depth(cm)				
	0-15	15-30	30-45	45-60	60-75
Location 2	2.8	2.8	1.9	2.2	2.5
Location 3	3.7	1.0	3.1	2.4	2.2
Location 4	2.4	2.6	1.9	1.6	1.5
Location 5	1.7	1.6	3.1	2.0	1.8
Location 6	1.3	1.1	1.2	1.6	1.4
AVERAGE	2.4	1.8	2.2	1.9	1.8

The CF of Cr was observed in the five soil depth across the different locations in an uneven distribution pattern in table 45. This uneven CF pattern could be due to varying soil properties across the locations and also variability in the sludge application to the plantation location. Two soil depths 0-15cm and 30-45cm in location 3 shows implication of considerable level of contamination ($3 < CF < 6$). The CF of Cr in the other soil depth across locations shows implication of Cr contamination at moderate level ($1 < CF < 3$).

The contamination factor of Arsenic and Mercury were not observed due to absence of background values which serves as a reference point for comparison. Studies shows that both As and Hg are absent in the soil of this region. Moreover, the anthropogenic activity of POME treatment in the soil has no effect of As and Hg contribution to the soil.

6.4.1 Degree of contamination (DC)

The degree of contamination (DC) is the sum of all contamination factors of the analyzed metals. DC was calculated via the equation 5 stated in chapter 5 above. Classification of the category of DC is shown in figure 28 below.

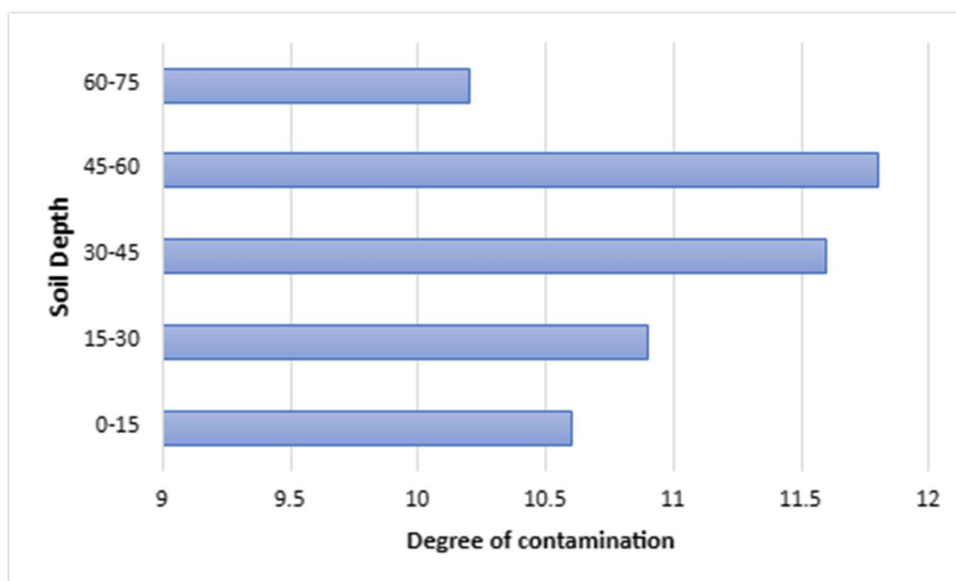


Figure 28: Heavy metal degree of contamination

From the figure above, the degree of contamination was in the range of moderate DC ($6d < 12$). The highest DC was obtained in depth (45-60cm) while the lowest was in the bottom soil (60-75cm). Continuous or long term anthropogenic activity of POME treatment in the soil could increase the DC.

6.5 Pollution load index (PLI)

Further assessment of the quality of the soils in the locations were carried out using the pollution load index. PLI gives a vivid picture of the extent of damage the contaminant has done to the soil. PLI helps to assess the quality of the environment (Igwe et al., 2021). The PLI of (Benarabi et al., 2021) was used in this study. The result shown in figure 29 below shows the PLI of the top and bottom soil layer of (0-15cm) and (60-75cm) lie in the category range of $PLI < 1.5$ with the implication of very low pollution of the soil as shown in table 19 above. The PLI of the soil depth (15-30cm), (30-45cm) and (45-60cm) lie in the category range of $1.5 \leq PLI < 2$ with implication of low pollution. According to (Igwe et al., 2021), $PLI < 1$ means perfection with the implication of no pollution. $PLI = 1$ implies that only background level of pollutants are present and $PLI > 1$ indicates site deterioration with a follow up measure for amelioration.

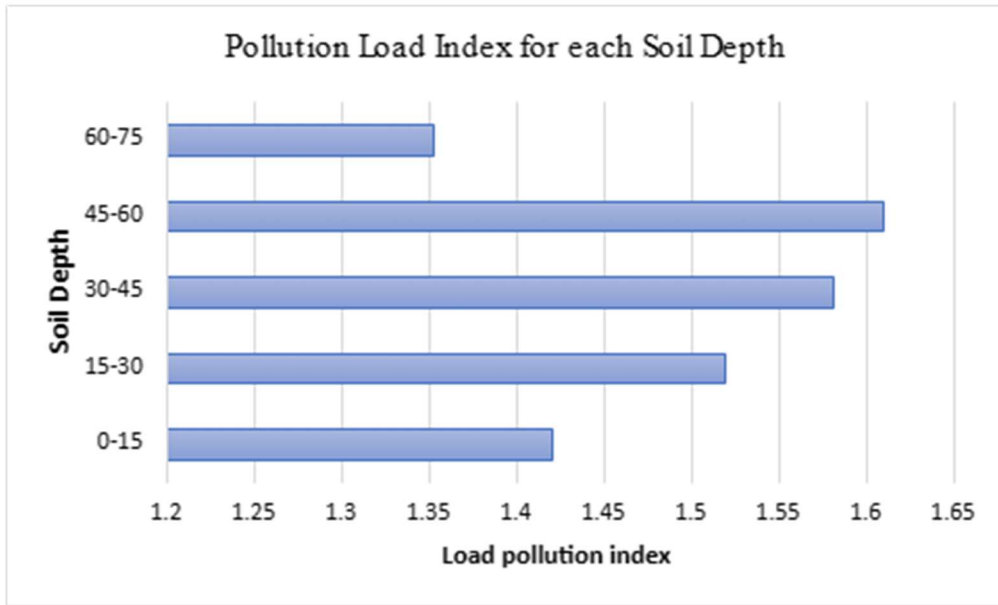


Figure 29: Pollution load index of heavy metals in locations

Chapter 7

7 Conclusions and recommendations

The study on the use of anaerobically digested treated POME as an organic fertilizer is important as a way of proffering solution to the harm caused by raw POME dumping to agricultural land and water bodies without treatment. Treated POME could improve the fertility of the soil and promote sustainable agricultural management. The potential of treated POME used as organic fertilizer cannot be overemphasized due to the characteristics of the effluent. POME richness in nutrient, organic matter, N, P, K and other essential nutrients makes it a potential suitable organic manure in agricultural soil.

This study was conducted to ascertain how suitable and sustainable anaerobically digested treated palm oil mill effluent could be used or recommended as organic fertilizers in oil palm plantation soils and other agricultural farmlands. Among the characteristics of anaerobically digested treated POME, is the heavy metal content. These heavy metals enter into POME in the anaerobic treatment reactor where it is used in enhancement of the micro-organism lives that decomposed the effluent. Also, heavy metals are naturally present in the soil globally from the weathering of soil parent material. This combination effects might result to the risk of increase heavy metal concentration in the soil. POME effect on heavy metal accumulation could be due to the composition of the POME, soil properties and the treatment methods. Heavy metal hazard is due to its environmental persistency, toxicity and bio-accumulative potential. It is therefore imperative to assess and monitor the concentration of heavy metal in soils in order to avoid or minimize the impact of these metals on human through food chain.

This study assessed the level of heavy metal accumulation of Cu, Mn, Zn, Ni, Pb, Cr, Cd, As Hg and determined the contamination and pollution level of the POME treated locations in southern Edo state of Nigeria. The study covered both the baseline soil and the POME treated soils. The results of the analysis showed increased concentration of heavy metals across the soil depth of the POME treated locations compared with the background soil. The concentration of these metals were found to be below the permissible limit set by WHO and various countries in the world. The ANOVA analysis

demonstrated a significant difference among the treated locations and the control soil with indication that POME treatment has effects on the soil locations. This increase in concentration of POME in the treated soil locations compared to the baseline soil proved the significant additions of heavy metals to the soil through the anthropogenic activities of POME ferti-irrigation. The soil was heavily impacted with essential metals (Cu, Mn, Zn, Ni), with Mn having the highest concentration in all. The non-essential metals (Pb, Cd, As, Cr, Hg) on the other hand was slightly impacted, with As and Hg undetected in most cases due to their low concentration in POME and this region. This outcome shows that the treated POME contribute significant amount of the essential heavy metal to the soil than the non-essential metal. The analysis of contamination factor, degree of contamination and pollution load index showed low to moderate contamination and pollution. This implication shows that a follow-up measure is needed to avoid further deterioration of the soils. Cd show lowest contamination factor with low contamination across the location. The conducted cluster analysis showed that location 6 has the closest similarities with the background soil (location 1).

This study recommends background soil to be kept and maintained in order to check heavy metal influence and excess on the long term use of the treated POME as manure. The level of Heavy metal contamination in the soil as a result of POME usage should be monitored and regularly assessed if POME should be use as manure. This can be achieved by regular testing of the soil to ensure the metals remain within permissible limit for sustainable agricultural practice. This procedure could help to check and ascertain the magnitude of soil contamination and pollution for quick remediation and also to ensure environmental safety and prevent potential contamination risks. A comprehensive risk assessment of heavy metal accumulations in anaerobically digested treated POME in soils should be conducted to ascertain the potential health risk to human.

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Appendices

Appendix 1. Analysis of variance

Mg - Descriptives									
	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum	
					Lower Bound	Upper Bound			
A	1.00	3	49.0200	.02000	.01155	48.9703	49.0697	49.00	49.04
	2.00	3	55.2900	.10000	.05774	55.0416	55.5384	55.19	55.39
	3.00	3	36.4900	.01000	.00577	36.4652	36.5148	36.48	36.50
	4.00	3	34.9800	.01000	.00577	34.9552	35.0048	34.97	34.99
	5.00	3	36.4800	.10000	.05774	36.2316	36.7284	36.38	36.58
	6.00	3	30.2100	.01000	.00577	30.1852	30.2348	30.20	30.22
	Total	18	40.4117	9.00878	2.12339	35.9317	44.8916	30.20	55.39
B	1.00	3	34.9800	.01000	.00577	34.9552	35.0048	34.97	34.99
	2.00	3	42.7500	.10000	.05774	42.5016	42.9984	42.65	42.85
	3.00	3	30.2100	.10000	.05774	29.9616	30.4584	30.11	30.31
	4.00	3	42.7500	.10000	.05774	42.5016	42.9984	42.65	42.85
	5.00	3	32.6400	.03000	.01732	32.5655	32.7145	32.61	32.67
	6.00	3	33.4800	.01000	.00577	33.4552	33.5048	33.47	33.49
	Total	18	36.1350	5.02770	1.18504	33.6348	38.6352	30.11	42.85
C	1.00	3	30.9600	.01000	.00577	30.9352	30.9848	30.95	30.97
	2.00	3	42.7500	.10000	.05774	42.5016	42.9984	42.65	42.85
	3.00	3	36.4800	.01000	.00577	36.4552	36.5048	36.47	36.49
	4.00	3	30.9600	.03000	.01732	30.8855	31.0345	30.93	30.99
	5.00	3	30.2100	.10000	.05774	29.9616	30.4584	30.11	30.31
	6.00	3	30.2100	.01000	.00577	30.1852	30.2348	30.20	30.22
	Total	18	33.5950	4.77039	1.12439	31.2227	35.9673	30.11	42.85
D	1.00	3	27.0000	.00000	.00000	27.0000	27.0000	27.00	27.00
	2.00	3	30.1000	.10000	.05774	29.8516	30.3484	30.00	30.20
	3.00	3	26.8800	.10000	.05774	26.6316	27.1284	26.78	26.98
	4.00	3	17.6700	.10000	.05774	17.4216	17.9184	17.57	17.77
	5.00	3	36.4800	.01000	.00577	36.4552	36.5048	36.47	36.49
	6.00	3	21.1200	.03000	.01732	21.0455	21.1945	21.09	21.15
	Total	18	26.5417	6.22913	1.46822	23.4440	29.6393	17.57	36.49
E	1.00	3	17.4900	.10000	.05774	17.2416	17.7384	17.39	17.59
	2.00	3	24.7500	.04000	.02309	24.6506	24.8494	24.71	24.79

3.00	3	19.5300	.02000	.01155	19.4803	19.5797	19.51	19.55
4.00	3	4.9400	.04000	.02309	4.8406	5.0394	4.90	4.98
5.00	3	19.0800	.01000	.00577	19.0552	19.1048	19.07	19.09
6.00	3	17.6000	.30000	.17321	16.8548	18.3452	17.30	17.90
Total	18	17.2317	6.18224	1.45717	14.1573	20.3060	4.90	24.79

Mg- Multiple Comparisons

LSD

Dependent Variable	(I) Location	(J) Location	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
A	1.00	2.00	-6.27000*	.04796	.000	-6.3745	-6.1655
		3.00	12.53000*	.04796	.000	12.4255	12.6345
		4.00	14.04000*	.04796	.000	13.9355	14.1445
		5.00	12.54000*	.04796	.000	12.4355	12.6445
		6.00	18.81000*	.04796	.000	18.7055	18.9145
	2.00	1.00	6.27000*	.04796	.000	6.1655	6.3745
		3.00	18.80000*	.04796	.000	18.6955	18.9045
		4.00	20.31000*	.04796	.000	20.2055	20.4145
		5.00	18.81000*	.04796	.000	18.7055	18.9145
		6.00	25.08000*	.04796	.000	24.9755	25.1845
	3.00	1.00	-12.53000*	.04796	.000	-12.6345	-12.4255
		2.00	-18.80000*	.04796	.000	-18.9045	-18.6955
		4.00	1.51000*	.04796	.000	1.4055	1.6145
		5.00	.01000	.04796	.838	-.0945	.1145
		6.00	6.28000*	.04796	.000	6.1755	6.3845
	4.00	1.00	-14.04000*	.04796	.000	-14.1445	-13.9355
		2.00	-20.31000*	.04796	.000	-20.4145	-20.2055
		3.00	-1.51000*	.04796	.000	-1.6145	-1.4055
		5.00	-1.50000*	.04796	.000	-1.6045	-1.3955
		6.00	4.77000*	.04796	.000	4.6655	4.8745
	5.00	1.00	-12.54000*	.04796	.000	-12.6445	-12.4355
		2.00	-18.81000*	.04796	.000	-18.9145	-18.7055
		3.00	-.01000	.04796	.838	-.1145	.0945
		4.00	1.50000*	.04796	.000	1.3955	1.6045
		6.00	6.27000*	.04796	.000	6.1655	6.3745
	6.00	1.00	-18.81000*	.04796	.000	-18.9145	-18.7055
		2.00	-25.08000*	.04796	.000	-25.1845	-24.9755
		3.00	-6.28000*	.04796	.000	-6.3845	-6.1755
		4.00	-4.77000*	.04796	.000	-4.8745	-4.6655
		5.00	-6.27000*	.04796	.000	-6.3745	-6.1655
B	1.00	2.00	-7.77000*	.05878	.000	-7.8981	-7.6419
		3.00	4.77000*	.05878	.000	4.6419	4.8981
		4.00	-7.77000*	.05878	.000	-7.8981	-7.6419
		5.00	2.34000*	.05878	.000	2.2119	2.4681
		6.00	1.50000*	.05878	.000	1.3719	1.6281
	2.00	1.00	7.77000*	.05878	.000	7.6419	7.8981
		3.00	12.54000*	.05878	.000	12.4119	12.6681
		4.00	.00000	.05878	1.000	-.1281	.1281

		5.00	10.11000*	.05878	.000	9.9819	10.2381	
		6.00	9.27000*	.05878	.000	9.1419	9.3981	
	3.00	1.00	-4.77000*	.05878	.000	-4.8981	-4.6419	
		2.00	-12.54000*	.05878	.000	-12.6681	-12.4119	
		4.00	-12.54000*	.05878	.000	-12.6681	-12.4119	
		5.00	-2.43000*	.05878	.000	-2.5581	-2.3019	
		6.00	-3.27000*	.05878	.000	-3.3981	-3.1419	
		4.00	1.00	7.77000*	.05878	.000	7.6419	7.8981
	2.00		.00000	.05878	1.000	-.1281	.1281	
	3.00		12.54000*	.05878	.000	12.4119	12.6681	
	5.00		10.11000*	.05878	.000	9.9819	10.2381	
	6.00		9.27000*	.05878	.000	9.1419	9.3981	
	5.00	1.00	-2.34000*	.05878	.000	-2.4681	-2.2119	
		2.00	-10.11000*	.05878	.000	-10.2381	-9.9819	
		3.00	2.43000*	.05878	.000	2.3019	2.5581	
		4.00	-10.11000*	.05878	.000	-10.2381	-9.9819	
		6.00	-.84000*	.05878	.000	-.9681	-.7119	
	6.00	1.00	-1.50000*	.05878	.000	-1.6281	-1.3719	
		2.00	-9.27000*	.05878	.000	-9.3981	-9.1419	
		3.00	3.27000*	.05878	.000	3.1419	3.3981	
		4.00	-9.27000*	.05878	.000	-9.3981	-9.1419	
		5.00	.84000*	.05878	.000	.7119	.9681	
	C	1.00	2.00	-11.79000*	.04853	.000	-11.8957	-11.6843
			3.00	-5.52000*	.04853	.000	-5.6257	-5.4143
4.00			.00000	.04853	1.000	-.1057	.1057	
5.00			.75000*	.04853	.000	.6443	.8557	
6.00			.75000*	.04853	.000	.6443	.8557	
2.00		1.00	11.79000*	.04853	.000	11.6843	11.8957	
		3.00	6.27000*	.04853	.000	6.1643	6.3757	
		4.00	11.79000*	.04853	.000	11.6843	11.8957	
		5.00	12.54000*	.04853	.000	12.4343	12.6457	
		6.00	12.54000*	.04853	.000	12.4343	12.6457	
3.00		1.00	5.52000*	.04853	.000	5.4143	5.6257	
		2.00	-6.27000*	.04853	.000	-6.3757	-6.1643	
		4.00	5.52000*	.04853	.000	5.4143	5.6257	
		5.00	6.27000*	.04853	.000	6.1643	6.3757	
		6.00	6.27000*	.04853	.000	6.1643	6.3757	
4.00		1.00	.00000	.04853	1.000	-.1057	.1057	
		2.00	-11.79000*	.04853	.000	-11.8957	-11.6843	

		3.00	-5.52000*	.04853	.000	-5.6257	-5.4143
		5.00	.75000*	.04853	.000	.6443	.8557
		6.00	.75000*	.04853	.000	.6443	.8557
	5.00	1.00	-.75000*	.04853	.000	-.8557	-.6443
		2.00	-12.54000*	.04853	.000	-12.6457	-12.4343
		3.00	-6.27000*	.04853	.000	-6.3757	-6.1643
		4.00	-.75000*	.04853	.000	-.8557	-.6443
		6.00	.00000	.04853	1.000	-.1057	.1057
	6.00	1.00	-.75000*	.04853	.000	-.8557	-.6443
		2.00	-12.54000*	.04853	.000	-12.6457	-12.4343
		3.00	-6.27000*	.04853	.000	-6.3757	-6.1643
		4.00	-.75000*	.04853	.000	-.8557	-.6443
		5.00	.00000	.04853	1.000	-.1057	.1057
D	1.00	2.00	-3.10000*	.05869	.000	-3.2279	-2.9721
		3.00	.12000	.05869	.063	-.0079	.2479
		4.00	9.33000*	.05869	.000	9.2021	9.4579
		5.00	-9.48000*	.05869	.000	-9.6079	-9.3521
		6.00	5.88000*	.05869	.000	5.7521	6.0079
	2.00	1.00	3.10000*	.05869	.000	2.9721	3.2279
		3.00	3.22000*	.05869	.000	3.0921	3.3479
		4.00	12.43000*	.05869	.000	12.3021	12.5579
		5.00	-6.38000*	.05869	.000	-6.5079	-6.2521
		6.00	8.98000*	.05869	.000	8.8521	9.1079
	3.00	1.00	-.12000	.05869	.063	-.2479	.0079
		2.00	-3.22000*	.05869	.000	-3.3479	-3.0921
		4.00	9.21000*	.05869	.000	9.0821	9.3379
		5.00	-9.60000*	.05869	.000	-9.7279	-9.4721
		6.00	5.76000*	.05869	.000	5.6321	5.8879
	4.00	1.00	-9.33000*	.05869	.000	-9.4579	-9.2021
		2.00	-12.43000*	.05869	.000	-12.5579	-12.3021
		3.00	-9.21000*	.05869	.000	-9.3379	-9.0821
		5.00	-18.81000*	.05869	.000	-18.9379	-18.6821
		6.00	-3.45000*	.05869	.000	-3.5779	-3.3221
	5.00	1.00	9.48000*	.05869	.000	9.3521	9.6079
		2.00	6.38000*	.05869	.000	6.2521	6.5079
		3.00	9.60000*	.05869	.000	9.4721	9.7279
		4.00	18.81000*	.05869	.000	18.6821	18.9379
		6.00	15.36000*	.05869	.000	15.2321	15.4879
	6.00	1.00	-5.88000*	.05869	.000	-6.0079	-5.7521

		2.00	-8.98000*	.05869	.000	-9.1079	-8.8521
		3.00	-5.76000*	.05869	.000	-5.8879	-5.6321
		4.00	3.45000*	.05869	.000	3.3221	3.5779
		5.00	-15.36000*	.05869	.000	-15.4879	-15.2321
E	1.00	2.00	-7.26000*	.10734	.000	-7.4939	-7.0261
		3.00	-2.04000*	.10734	.000	-2.2739	-1.8061
		4.00	12.55000*	.10734	.000	12.3161	12.7839
		5.00	-1.59000*	.10734	.000	-1.8239	-1.3561
		6.00	-.11000	.10734	.326	-.3439	.1239
	2.00	1.00	7.26000*	.10734	.000	7.0261	7.4939
		3.00	5.22000*	.10734	.000	4.9861	5.4539
		4.00	19.81000*	.10734	.000	19.5761	20.0439
		5.00	5.67000*	.10734	.000	5.4361	5.9039
		6.00	7.15000*	.10734	.000	6.9161	7.3839
	3.00	1.00	2.04000*	.10734	.000	1.8061	2.2739
		2.00	-5.22000*	.10734	.000	-5.4539	-4.9861
		4.00	14.59000*	.10734	.000	14.3561	14.8239
		5.00	.45000*	.10734	.001	.2161	.6839
		6.00	1.93000*	.10734	.000	1.6961	2.1639
	4.00	1.00	-12.55000*	.10734	.000	-12.7839	-12.3161
		2.00	-19.81000*	.10734	.000	-20.0439	-19.5761
		3.00	-14.59000*	.10734	.000	-14.8239	-14.3561
		5.00	-14.14000*	.10734	.000	-14.3739	-13.9061
		6.00	-12.66000*	.10734	.000	-12.8939	-12.4261
	5.00	1.00	1.59000*	.10734	.000	1.3561	1.8239
		2.00	-5.67000*	.10734	.000	-5.9039	-5.4361
		3.00	-.45000*	.10734	.001	-.6839	-.2161
		4.00	14.14000*	.10734	.000	13.9061	14.3739
6.00		1.48000*	.10734	.000	1.2461	1.7139	
6.00	1.00	.11000	.10734	.326	-.1239	.3439	
	2.00	-7.15000*	.10734	.000	-7.3839	-6.9161	
	3.00	-1.93000*	.10734	.000	-2.1639	-1.6961	
	4.00	12.66000*	.10734	.000	12.4261	12.8939	
	5.00	-1.48000*	.10734	.000	-1.7139	-1.2461	

*. The mean difference is significant at the 0.05 level.

Hg - Descriptives

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum	
					Lower Bound	Upper Bound			
A	1.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
	2.00	3	.0100	.01000	.00577	-.0148	.0348	.00	.02
	3.00	3	.0100	.00000	.00000	.0100	.0100	.01	.01
	4.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
	5.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
	6.00	3	.0100	.01000	.00577	-.0148	.0348	.00	.02
	Total	18	.0050	.00707	.00167	.0015	.0085	.00	.02
B	1.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
	2.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
	3.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
	4.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
	5.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
	6.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
	Total	18	.0000	.00000	.00000	.0000	.0000	.00	.00
C	1.00	3	.3333	.57735	.33333	-1.1009	1.7676	.00	1.00
	2.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
	3.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
	4.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
	5.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
	6.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
	Total	18	.0556	.23570	.05556	-.0617	.1728	.00	1.00
D	1.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
	2.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
	3.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
	4.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
	5.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
	6.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
	Total	18	.0000	.00000	.00000	.0000	.0000	.00	.00
E	1.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
	2.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
	3.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
	4.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
	5.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
	6.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
	Total	18	.0000	.00000	.00000	.0000	.0000	.00	.00

Hg - Multiple Comparisons

LSD

Dependent Variable	(I) Location	(J) Location	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
A	1.00	2.00	-.01000	.00471	.055	-.0203	.0003
		3.00	-.01000	.00471	.055	-.0203	.0003
		4.00	.00000	.00471	1.000	-.0103	.0103
		5.00	.00000	.00471	1.000	-.0103	.0103
		6.00	-.01000	.00471	.055	-.0203	.0003
	2.00	1.00	.01000	.00471	.055	-.0003	.0203
		3.00	.00000	.00471	1.000	-.0103	.0103
		4.00	.01000	.00471	.055	-.0003	.0203
		5.00	.01000	.00471	.055	-.0003	.0203
		6.00	.00000	.00471	1.000	-.0103	.0103
	3.00	1.00	.01000	.00471	.055	-.0003	.0203
		2.00	.00000	.00471	1.000	-.0103	.0103
		4.00	.01000	.00471	.055	-.0003	.0203
		5.00	.01000	.00471	.055	-.0003	.0203
		6.00	.00000	.00471	1.000	-.0103	.0103
	4.00	1.00	.00000	.00471	1.000	-.0103	.0103
		2.00	-.01000	.00471	.055	-.0203	.0003
		3.00	-.01000	.00471	.055	-.0203	.0003
		5.00	.00000	.00471	1.000	-.0103	.0103
		6.00	-.01000	.00471	.055	-.0203	.0003
	5.00	1.00	.00000	.00471	1.000	-.0103	.0103
		2.00	-.01000	.00471	.055	-.0203	.0003
		3.00	-.01000	.00471	.055	-.0203	.0003
		4.00	.00000	.00471	1.000	-.0103	.0103
		6.00	-.01000	.00471	.055	-.0203	.0003
	6.00	1.00	.01000	.00471	.055	-.0003	.0203
		2.00	.00000	.00471	1.000	-.0103	.0103
		3.00	.00000	.00471	1.000	-.0103	.0103
		4.00	.01000	.00471	.055	-.0003	.0203
		5.00	.01000	.00471	.055	-.0003	.0203
C	1.00	2.00	.33333	.19245	.109	-.0860	.7526
		3.00	.33333	.19245	.109	-.0860	.7526
		4.00	.33333	.19245	.109	-.0860	.7526
		5.00	.33333	.19245	.109	-.0860	.7526
		6.00	.33333	.19245	.109	-.0860	.7526
	2.00	1.00	-.33333	.19245	.109	-.7526	.0860

		3.00	.00000	.19245	1.000	-.4193	.4193	
		4.00	.00000	.19245	1.000	-.4193	.4193	
		5.00	.00000	.19245	1.000	-.4193	.4193	
		6.00	.00000	.19245	1.000	-.4193	.4193	
	3.00		1.00	-.33333	.19245	.109	-.7526	.0860
			2.00	.00000	.19245	1.000	-.4193	.4193
			4.00	.00000	.19245	1.000	-.4193	.4193
			5.00	.00000	.19245	1.000	-.4193	.4193
			6.00	.00000	.19245	1.000	-.4193	.4193
	4.00		1.00	-.33333	.19245	.109	-.7526	.0860
			2.00	.00000	.19245	1.000	-.4193	.4193
			3.00	.00000	.19245	1.000	-.4193	.4193
			5.00	.00000	.19245	1.000	-.4193	.4193
			6.00	.00000	.19245	1.000	-.4193	.4193
	5.00		1.00	-.33333	.19245	.109	-.7526	.0860
			2.00	.00000	.19245	1.000	-.4193	.4193
			3.00	.00000	.19245	1.000	-.4193	.4193
			4.00	.00000	.19245	1.000	-.4193	.4193
			6.00	.00000	.19245	1.000	-.4193	.4193
	6.00		1.00	-.33333	.19245	.109	-.7526	.0860
			2.00	.00000	.19245	1.000	-.4193	.4193
			3.00	.00000	.19245	1.000	-.4193	.4193
			4.00	.00000	.19245	1.000	-.4193	.4193
			5.00	.00000	.19245	1.000	-.4193	.4193

Cu - Descriptives

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum	
					Lower Bound	Upper Bound			
A	1.00	3	8.6100	.01000	.00577	8.5852	8.6348	8.60	8.62
	2.00	3	14.0600	.01000	.00577	14.0352	14.0848	14.05	14.07
	3.00	3	16.7200	.02000	.01155	16.6703	16.7697	16.70	16.74
	4.00	3	17.7600	.04000	.02309	17.6606	17.8594	17.72	17.80
	5.00	3	12.1600	.01000	.00577	12.1352	12.1848	12.15	12.17
	6.00	3	12.1600	.10000	.05774	11.9116	12.4084	12.06	12.26
	Total	18	13.5783	3.15215	.74297	12.0108	15.1459	8.60	17.80
B	1.00	3	6.7200	.10000	.05774	6.4716	6.9684	6.62	6.82
	2.00	3	12.1600	.01000	.00577	12.1352	12.1848	12.15	12.17
	3.00	3	12.1600	.01000	.00577	12.1352	12.1848	12.15	12.17
	4.00	3	13.3200	.01000	.00577	13.2952	13.3448	13.31	13.33
	5.00	3	8.8200	.01000	.00577	8.7952	8.8448	8.81	8.83
	6.00	3	8.5400	.10000	.05774	8.2916	8.7884	8.44	8.64
	Total	18	10.2867	2.45512	.57868	9.0658	11.5076	6.62	13.33
C	1.00	3	6.7200	.02000	.01155	6.6703	6.7697	6.70	6.74
	2.00	3	10.2400	.10000	.05774	9.9916	10.4884	10.14	10.34
	3.00	3	11.5600	.10000	.05774	11.3116	11.8084	11.46	11.66
	4.00	3	12.1600	.03000	.01732	12.0855	12.2345	12.13	12.19
	5.00	3	7.1400	.02000	.01155	7.0903	7.1897	7.12	7.16
	6.00	3	6.7200	.01000	.00577	6.6952	6.7448	6.71	6.73
	Total	18	9.0900	2.37261	.55923	7.9101	10.2699	6.70	12.19
D	1.00	3	6.7200	.01000	.00577	6.6952	6.7448	6.71	6.73
	2.00	3	9.2500	.10000	.05774	9.0016	9.4984	9.15	9.35
	3.00	3	7.9567	.03055	.01764	7.8808	8.0326	7.93	7.99
	4.00	3	6.7200	.02000	.01155	6.6703	6.7697	6.70	6.74
	5.00	3	7.6000	.10000	.05774	7.3516	7.8484	7.50	7.70
	6.00	3	5.8800	.01000	.00577	5.8552	5.9048	5.87	5.89
	Total	18	7.3544	1.11219	.26215	6.8014	7.9075	5.87	9.35
E	1.00	3	4.5200	.02000	.01155	4.4703	4.5697	4.50	4.54
	2.00	3	8.5600	.01000	.00577	8.5352	8.5848	8.55	8.57
	3.00	3	6.7200	.03000	.01732	6.6455	6.7945	6.69	6.75
	4.00	3	1.1200	.02000	.01155	1.0703	1.1697	1.10	1.14
	5.00	3	1.1467	.11015	.06360	.8730	1.4203	1.02	1.22
	6.00	3	1.5367	.03512	.02028	1.4494	1.6239	1.50	1.57
	Total	18	3.9339	2.99854	.70676	2.4428	5.4250	1.02	8.57

CU - Multiple Comparisons

LSD

Dependent Variable	(I) Location	(J) Location	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
A	1.00	2.00	-5.45000*	.03697	.000	-5.5305	-5.3695
		3.00	-8.11000*	.03697	.000	-8.1905	-8.0295
		4.00	-9.15000*	.03697	.000	-9.2305	-9.0695
		5.00	-3.55000*	.03697	.000	-3.6305	-3.4695
		6.00	-3.55000*	.03697	.000	-3.6305	-3.4695
	2.00	1.00	5.45000*	.03697	.000	5.3695	5.5305
		3.00	-2.66000*	.03697	.000	-2.7405	-2.5795
		4.00	-3.70000*	.03697	.000	-3.7805	-3.6195
		5.00	1.90000*	.03697	.000	1.8195	1.9805
		6.00	1.90000*	.03697	.000	1.8195	1.9805
	3.00	1.00	8.11000*	.03697	.000	8.0295	8.1905
		2.00	2.66000*	.03697	.000	2.5795	2.7405
		4.00	-1.04000*	.03697	.000	-1.1205	-.9595
		5.00	4.56000*	.03697	.000	4.4795	4.6405
		6.00	4.56000*	.03697	.000	4.4795	4.6405
	4.00	1.00	9.15000*	.03697	.000	9.0695	9.2305
		2.00	3.70000*	.03697	.000	3.6195	3.7805
		3.00	1.04000*	.03697	.000	.9595	1.1205
		5.00	5.60000*	.03697	.000	5.5195	5.6805
		6.00	5.60000*	.03697	.000	5.5195	5.6805
	5.00	1.00	3.55000*	.03697	.000	3.4695	3.6305
		2.00	-1.90000*	.03697	.000	-1.9805	-1.8195
		3.00	-4.56000*	.03697	.000	-4.6405	-4.4795
		4.00	-5.60000*	.03697	.000	-5.6805	-5.5195
		6.00	.00000	.03697	1.000	-.0805	.0805
	6.00	1.00	3.55000*	.03697	.000	3.4695	3.6305
		2.00	-1.90000*	.03697	.000	-1.9805	-1.8195
		3.00	-4.56000*	.03697	.000	-4.6405	-4.4795
		4.00	-5.60000*	.03697	.000	-5.6805	-5.5195
		5.00	.00000	.03697	1.000	-.0805	.0805
B	1.00	2.00	-5.44000*	.04761	.000	-5.5437	-5.3363
		3.00	-5.44000*	.04761	.000	-5.5437	-5.3363
		4.00	-6.60000*	.04761	.000	-6.7037	-6.4963
		5.00	-2.10000*	.04761	.000	-2.2037	-1.9963

		6.00	-1.82000*	.04761	.000	-1.9237	-1.7163
	2.00	1.00	5.44000*	.04761	.000	5.3363	5.5437
		3.00	.00000	.04761	1.000	-.1037	.1037
		4.00	-1.16000*	.04761	.000	-1.2637	-1.0563
		5.00	3.34000*	.04761	.000	3.2363	3.4437
		6.00	3.62000*	.04761	.000	3.5163	3.7237
		3.00	1.00	5.44000*	.04761	.000	5.3363
	2.00		.00000	.04761	1.000	-.1037	.1037
	4.00		-1.16000*	.04761	.000	-1.2637	-1.0563
	5.00		3.34000*	.04761	.000	3.2363	3.4437
	6.00		3.62000*	.04761	.000	3.5163	3.7237
	4.00	1.00	6.60000*	.04761	.000	6.4963	6.7037
		2.00	1.16000*	.04761	.000	1.0563	1.2637
		3.00	1.16000*	.04761	.000	1.0563	1.2637
		5.00	4.50000*	.04761	.000	4.3963	4.6037
		6.00	4.78000*	.04761	.000	4.6763	4.8837
		5.00	1.00	2.10000*	.04761	.000	1.9963
	2.00		-3.34000*	.04761	.000	-3.4437	-3.2363
	3.00		-3.34000*	.04761	.000	-3.4437	-3.2363
	4.00		-4.50000*	.04761	.000	-4.6037	-4.3963
	6.00		.28000*	.04761	.000	.1763	.3837
	6.00	1.00	1.82000*	.04761	.000	1.7163	1.9237
		2.00	-3.62000*	.04761	.000	-3.7237	-3.5163
		3.00	-3.62000*	.04761	.000	-3.7237	-3.5163
		4.00	-4.78000*	.04761	.000	-4.8837	-4.6763
		5.00	-.28000*	.04761	.000	-.3837	-.1763
C	1.00	2.00	-3.52000*	.04922	.000	-3.6272	-3.4128
		3.00	-4.84000*	.04922	.000	-4.9472	-4.7328
		4.00	-5.44000*	.04922	.000	-5.5472	-5.3328
		5.00	-.42000*	.04922	.000	-.5272	-.3128
		6.00	.00000	.04922	1.000	-.1072	.1072
	2.00	1.00	3.52000*	.04922	.000	3.4128	3.6272
		3.00	-1.32000*	.04922	.000	-1.4272	-1.2128
		4.00	-1.92000*	.04922	.000	-2.0272	-1.8128
		5.00	3.10000*	.04922	.000	2.9928	3.2072
		6.00	3.52000*	.04922	.000	3.4128	3.6272
	3.00	1.00	4.84000*	.04922	.000	4.7328	4.9472
		2.00	1.32000*	.04922	.000	1.2128	1.4272
		4.00	-.60000*	.04922	.000	-.7072	-.4928

		5.00	4.42000*	.04922	.000	4.3128	4.5272	
		6.00	4.84000*	.04922	.000	4.7328	4.9472	
	4.00	1.00	5.44000*	.04922	.000	5.3328	5.5472	
		2.00	1.92000*	.04922	.000	1.8128	2.0272	
		3.00	.60000*	.04922	.000	.4928	.7072	
		5.00	5.02000*	.04922	.000	4.9128	5.1272	
		6.00	5.44000*	.04922	.000	5.3328	5.5472	
		5.00	1.00	.42000*	.04922	.000	.3128	.5272
	2.00		-3.10000*	.04922	.000	-3.2072	-2.9928	
	3.00		-4.42000*	.04922	.000	-4.5272	-4.3128	
	4.00		-5.02000*	.04922	.000	-5.1272	-4.9128	
	6.00		.42000*	.04922	.000	.3128	.5272	
	6.00	1.00	.00000	.04922	1.000	-.1072	.1072	
		2.00	-3.52000*	.04922	.000	-3.6272	-3.4128	
		3.00	-4.84000*	.04922	.000	-4.9472	-4.7328	
		4.00	-5.44000*	.04922	.000	-5.5472	-5.3328	
		5.00	-.42000*	.04922	.000	-.5272	-.3128	
	D	1.00	2.00	-2.53000*	.04891	.000	-2.6366	-2.4234
			3.00	-1.23667*	.04891	.000	-1.3432	-1.1301
			4.00	.00000	.04891	1.000	-.1066	.1066
5.00			-.88000*	.04891	.000	-.9866	-.7734	
6.00			.84000*	.04891	.000	.7334	.9466	
2.00		1.00	2.53000*	.04891	.000	2.4234	2.6366	
		3.00	1.29333*	.04891	.000	1.1868	1.3999	
		4.00	2.53000*	.04891	.000	2.4234	2.6366	
		5.00	1.65000*	.04891	.000	1.5434	1.7566	
		6.00	3.37000*	.04891	.000	3.2634	3.4766	
3.00		1.00	1.23667*	.04891	.000	1.1301	1.3432	
		2.00	-1.29333*	.04891	.000	-1.3999	-1.1868	
		4.00	1.23667*	.04891	.000	1.1301	1.3432	
		5.00	.35667*	.04891	.000	.2501	.4632	
		6.00	2.07667*	.04891	.000	1.9701	2.1832	
4.00		1.00	.00000	.04891	1.000	-.1066	.1066	
		2.00	-2.53000*	.04891	.000	-2.6366	-2.4234	
		3.00	-1.23667*	.04891	.000	-1.3432	-1.1301	
		5.00	-.88000*	.04891	.000	-.9866	-.7734	
		6.00	.84000*	.04891	.000	.7334	.9466	
5.00	1.00	.88000*	.04891	.000	.7734	.9866		
	2.00	-1.65000*	.04891	.000	-1.7566	-1.5434		

		3.00	-0.35667*	.04891	.000	-.4632	-.2501	
		4.00	.88000*	.04891	.000	.7734	.9866	
		6.00	1.72000*	.04891	.000	1.6134	1.8266	
	6.00	1.00	-.84000*	.04891	.000	-.9466	-.7334	
		2.00	-3.37000*	.04891	.000	-3.4766	-3.2634	
		3.00	-2.07667*	.04891	.000	-2.1832	-1.9701	
		4.00	-.84000*	.04891	.000	-.9466	-.7334	
		5.00	-1.72000*	.04891	.000	-1.8266	-1.6134	
	E	1.00	2.00	-4.04000*	.04105	.000	-4.1294	-3.9506
			3.00	-2.20000*	.04105	.000	-2.2894	-2.1106
4.00			3.40000*	.04105	.000	3.3106	3.4894	
5.00			3.37333*	.04105	.000	3.2839	3.4628	
6.00			2.98333*	.04105	.000	2.8939	3.0728	
2.00		1.00	4.04000*	.04105	.000	3.9506	4.1294	
		3.00	1.84000*	.04105	.000	1.7506	1.9294	
		4.00	7.44000*	.04105	.000	7.3506	7.5294	
		5.00	7.41333*	.04105	.000	7.3239	7.5028	
		6.00	7.02333*	.04105	.000	6.9339	7.1128	
3.00		1.00	2.20000*	.04105	.000	2.1106	2.2894	
		2.00	-1.84000*	.04105	.000	-1.9294	-1.7506	
		4.00	5.60000*	.04105	.000	5.5106	5.6894	
		5.00	5.57333*	.04105	.000	5.4839	5.6628	
		6.00	5.18333*	.04105	.000	5.0939	5.2728	
4.00		1.00	-3.40000*	.04105	.000	-3.4894	-3.3106	
		2.00	-7.44000*	.04105	.000	-7.5294	-7.3506	
		3.00	-5.60000*	.04105	.000	-5.6894	-5.5106	
		5.00	-.02667	.04105	.528	-.1161	.0628	
		6.00	-.41667*	.04105	.000	-.5061	-.3272	
5.00		1.00	-3.37333*	.04105	.000	-3.4628	-3.2839	
		2.00	-7.41333*	.04105	.000	-7.5028	-7.3239	
		3.00	-5.57333*	.04105	.000	-5.6628	-5.4839	
		4.00	.02667	.04105	.528	-.0628	.1161	
		6.00	-.39000*	.04105	.000	-.4794	-.3006	
6.00	1.00	-2.98333*	.04105	.000	-3.0728	-2.8939		
	2.00	-7.02333*	.04105	.000	-7.1128	-6.9339		
	3.00	-5.18333*	.04105	.000	-5.2728	-5.0939		
	4.00	.41667*	.04105	.000	.3272	.5061		
	5.00	.39000*	.04105	.000	.3006	.4794		

As - Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
						A	1.00		
2.00	3	.0500	.01000	.00577	.0252		.0748	.04	.06
3.00	3	.0600	.02000	.01155	.0103		.1097	.04	.08
4.00	3	.0200	.01000	.00577	-.0048		.0448	.01	.03
5.00	3	.0000	.00000	.00000	.0000		.0000	.00	.00
6.00	3	.0500	.04000	.02309	-.0494		.1494	.01	.09
Total	18	.0300	.02990	.00705	.0151		.0449	.00	.09
B	1.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
	2.00	3	.0100	.01000	.00577	-.0148	.0348	.00	.02
	3.00	3	.0100	.01000	.00577	-.0148	.0348	.00	.02
	4.00	3	.0100	.01000	.00577	-.0148	.0348	.00	.02
	5.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
	6.00	3	.5000	.10000	.05774	.2516	.7484	.40	.60
	Total	18	.0883	.19267	.04541	-.0075	.1841	.00	.60
C	1.00	3	.3333	.57735	.33333	-1.1009	1.7676	.00	1.00
	2.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
	3.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
	4.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
	5.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
	6.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
	Total	18	.0556	.23570	.05556	-.0617	.1728	.00	1.00
D	1.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
	2.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
	3.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
	4.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
	5.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
	6.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
	Total	18	.0000	.00000	.00000	.0000	.0000	.00	.00
E	1.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
	2.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
	3.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
	4.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
	5.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
	6.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
	Total	18	.0000	.00000	.00000	.0000	.0000	.00	.00

As - Multiple Comparisons

LSD

Dependent Variable	(I) Location	(J) Location	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
A	1.00	2.00	-.05000*	.01563	.008	-.0841	-.0159
		3.00	-.06000*	.01563	.002	-.0941	-.0259
		4.00	-.02000	.01563	.225	-.0541	.0141
		5.00	.00000	.01563	1.000	-.0341	.0341
		6.00	-.05000*	.01563	.008	-.0841	-.0159
	2.00	1.00	.05000*	.01563	.008	.0159	.0841
		3.00	-.01000	.01563	.534	-.0441	.0241
		4.00	.03000	.01563	.079	-.0041	.0641
		5.00	.05000*	.01563	.008	.0159	.0841
		6.00	.00000	.01563	1.000	-.0341	.0341
	3.00	1.00	.06000*	.01563	.002	.0259	.0941
		2.00	.01000	.01563	.534	-.0241	.0441
		4.00	.04000*	.01563	.025	.0059	.0741
		5.00	.06000*	.01563	.002	.0259	.0941
		6.00	.01000	.01563	.534	-.0241	.0441
	4.00	1.00	.02000	.01563	.225	-.0141	.0541
		2.00	-.03000	.01563	.079	-.0641	.0041
		3.00	-.04000*	.01563	.025	-.0741	-.0059
		5.00	.02000	.01563	.225	-.0141	.0541
		6.00	-.03000	.01563	.079	-.0641	.0041
	5.00	1.00	.00000	.01563	1.000	-.0341	.0341
		2.00	-.05000*	.01563	.008	-.0841	-.0159
		3.00	-.06000*	.01563	.002	-.0941	-.0259
		4.00	-.02000	.01563	.225	-.0541	.0141
		6.00	-.05000*	.01563	.008	-.0841	-.0159
	6.00	1.00	.05000*	.01563	.008	.0159	.0841
		2.00	.00000	.01563	1.000	-.0341	.0341
		3.00	-.01000	.01563	.534	-.0441	.0241
		4.00	.03000	.01563	.079	-.0041	.0641
		5.00	.05000*	.01563	.008	.0159	.0841
B	1.00	2.00	-.01000	.03383	.773	-.0837	.0637
		3.00	-.01000	.03383	.773	-.0837	.0637
		4.00	-.01000	.03383	.773	-.0837	.0637
		5.00	.00000	.03383	1.000	-.0737	.0737

	2.00	6.00	-.50000*	.03383	.000	-.5737	-.4263	
		1.00	.01000	.03383	.773	-.0637	.0837	
		3.00	.00000	.03383	1.000	-.0737	.0737	
		4.00	.00000	.03383	1.000	-.0737	.0737	
		5.00	.01000	.03383	.773	-.0637	.0837	
		6.00	-.49000*	.03383	.000	-.5637	-.4163	
	3.00	1.00	.01000	.03383	.773	-.0637	.0837	
		2.00	.00000	.03383	1.000	-.0737	.0737	
		4.00	.00000	.03383	1.000	-.0737	.0737	
		5.00	.01000	.03383	.773	-.0637	.0837	
		6.00	-.49000*	.03383	.000	-.5637	-.4163	
	4.00	1.00	.01000	.03383	.773	-.0637	.0837	
		2.00	.00000	.03383	1.000	-.0737	.0737	
		3.00	.00000	.03383	1.000	-.0737	.0737	
		5.00	.01000	.03383	.773	-.0637	.0837	
		6.00	-.49000*	.03383	.000	-.5637	-.4163	
	5.00	1.00	.00000	.03383	1.000	-.0737	.0737	
		2.00	-.01000	.03383	.773	-.0837	.0637	
		3.00	-.01000	.03383	.773	-.0837	.0637	
		4.00	-.01000	.03383	.773	-.0837	.0637	
		6.00	-.50000*	.03383	.000	-.5737	-.4263	
	6.00	1.00	.50000*	.03383	.000	.4263	.5737	
		2.00	.49000*	.03383	.000	.4163	.5637	
		3.00	.49000*	.03383	.000	.4163	.5637	
		4.00	.49000*	.03383	.000	.4163	.5637	
		5.00	.50000*	.03383	.000	.4263	.5737	
	C	1.00	2.00	.33333	.19245	.109	-.0860	.7526
			3.00	.33333	.19245	.109	-.0860	.7526
			4.00	.33333	.19245	.109	-.0860	.7526
			5.00	.33333	.19245	.109	-.0860	.7526
6.00			.33333	.19245	.109	-.0860	.7526	
2.00		1.00	-.33333	.19245	.109	-.7526	.0860	
		3.00	.00000	.19245	1.000	-.4193	.4193	
		4.00	.00000	.19245	1.000	-.4193	.4193	
		5.00	.00000	.19245	1.000	-.4193	.4193	
		6.00	.00000	.19245	1.000	-.4193	.4193	
3.00		1.00	-.33333	.19245	.109	-.7526	.0860	
		2.00	.00000	.19245	1.000	-.4193	.4193	
		4.00	.00000	.19245	1.000	-.4193	.4193	

		5.00	.00000	.19245	1.000	-.4193	.4193
		6.00	.00000	.19245	1.000	-.4193	.4193
	4.00	1.00	-.33333	.19245	.109	-.7526	.0860
		2.00	.00000	.19245	1.000	-.4193	.4193
		3.00	.00000	.19245	1.000	-.4193	.4193
		5.00	.00000	.19245	1.000	-.4193	.4193
		6.00	.00000	.19245	1.000	-.4193	.4193
		6.00	.00000	.19245	1.000	-.4193	.4193
	5.00	1.00	-.33333	.19245	.109	-.7526	.0860
		2.00	.00000	.19245	1.000	-.4193	.4193
		3.00	.00000	.19245	1.000	-.4193	.4193
		4.00	.00000	.19245	1.000	-.4193	.4193
		5.00	.00000	.19245	1.000	-.4193	.4193
		6.00	.00000	.19245	1.000	-.4193	.4193
	6.00	1.00	-.33333	.19245	.109	-.7526	.0860
		2.00	.00000	.19245	1.000	-.4193	.4193
		3.00	.00000	.19245	1.000	-.4193	.4193
		4.00	.00000	.19245	1.000	-.4193	.4193
		5.00	.00000	.19245	1.000	-.4193	.4193
		6.00	.00000	.19245	1.000	-.4193	.4193

*. The mean difference is significant at the 0.05 level.

Ni - Multiple Comparisons

LSD

Dependent Variable	(I) Location	(J) Location	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
A	1.00	2.00	-.08000	.04940	.131	-.1876	.0276
		3.00	-.16000*	.04940	.007	-.2676	-.0524
		4.00	-.35333*	.04940	.000	-.4610	-.2457
		5.00	-.19333*	.04940	.002	-.3010	-.0857
		6.00	-.47000*	.04940	.000	-.5776	-.3624
	2.00	1.00	.08000	.04940	.131	-.0276	.1876
		3.00	-.08000	.04940	.131	-.1876	.0276
		4.00	-.27333*	.04940	.000	-.3810	-.1657
		5.00	-.11333*	.04940	.041	-.2210	-.0057
		6.00	-.39000*	.04940	.000	-.4976	-.2824
	3.00	1.00	.16000*	.04940	.007	.0524	.2676
		2.00	.08000	.04940	.131	-.0276	.1876
		4.00	-.19333*	.04940	.002	-.3010	-.0857
		5.00	-.03333	.04940	.513	-.1410	.0743
		6.00	-.31000*	.04940	.000	-.4176	-.2024
	4.00	1.00	.35333*	.04940	.000	.2457	.4610
		2.00	.27333*	.04940	.000	.1657	.3810
		3.00	.19333*	.04940	.002	.0857	.3010
		5.00	.16000*	.04940	.007	.0524	.2676
		6.00	-.11667*	.04940	.036	-.2243	-.0090
	5.00	1.00	.19333*	.04940	.002	.0857	.3010
		2.00	.11333*	.04940	.041	.0057	.2210
		3.00	.03333	.04940	.513	-.0743	.1410
		4.00	-.16000*	.04940	.007	-.2676	-.0524
		6.00	-.27667*	.04940	.000	-.3843	-.1690
	6.00	1.00	.47000*	.04940	.000	.3624	.5776
		2.00	.39000*	.04940	.000	.2824	.4976
		3.00	.31000*	.04940	.000	.2024	.4176
		4.00	.11667*	.04940	.036	.0090	.2243
		5.00	.27667*	.04940	.000	.1690	.3843
B	1.00	2.00	-.04667	.03507	.208	-.1231	.0297
		3.00	-.17667*	.03507	.000	-.2531	-.1003
		4.00	-.46667*	.03507	.000	-.5431	-.3903
		5.00	-.22000*	.03507	.000	-.2964	-.1436
		6.00	-.41667*	.03507	.000	-.4931	-.3403
	2.00	1.00	.04667	.03507	.208	-.0297	.1231
		3.00	-.13000*	.03507	.003	-.2064	-.0536
		4.00	-.42000*	.03507	.000	-.4964	-.3436
		5.00	-.17333*	.03507	.000	-.2497	-.0969

		6.00		-.37000*	.03507	.000	-.4464	-.2936
	3.00	1.00		.17667*	.03507	.000	.1003	.2531
		2.00		.13000*	.03507	.003	.0536	.2064
		4.00		-.29000*	.03507	.000	-.3664	-.2136
		5.00		-.04333	.03507	.240	-.1197	.0331
		6.00		-.24000*	.03507	.000	-.3164	-.1636
		4.00	1.00		.46667*	.03507	.000	.3903
	2.00			.42000*	.03507	.000	.3436	.4964
	3.00			.29000*	.03507	.000	.2136	.3664
	5.00			.24667*	.03507	.000	.1703	.3231
	6.00			.05000	.03507	.179	-.0264	.1264
	5.00	1.00		.22000*	.03507	.000	.1436	.2964
		2.00		.17333*	.03507	.000	.0969	.2497
		3.00		.04333	.03507	.240	-.0331	.1197
		4.00		-.24667*	.03507	.000	-.3231	-.1703
		6.00		-.19667*	.03507	.000	-.2731	-.1203
	6.00	1.00		.41667*	.03507	.000	.3403	.4931
		2.00		.37000*	.03507	.000	.2936	.4464
		3.00		.24000*	.03507	.000	.1636	.3164
		4.00		-.05000	.03507	.179	-.1264	.0264
		5.00		.19667*	.03507	.000	.1203	.2731
C	1.00	2.00		-.10333*	.00544	.000	-.1152	-.0915
		3.00		-.21000*	.00544	.000	-.2219	-.1981
		4.00		-.31667*	.00544	.000	-.3285	-.3048
		5.00		-.14000*	.00544	.000	-.1519	-.1281
		6.00		-.10000*	.00544	.000	-.1119	-.0881
	2.00	1.00		.10333*	.00544	.000	.0915	.1152
		3.00		-.10667*	.00544	.000	-.1185	-.0948
		4.00		-.21333*	.00544	.000	-.2252	-.2015
		5.00		-.03667*	.00544	.000	-.0485	-.0248
		6.00		.00333	.00544	.552	-.0085	.0152
	3.00	1.00		.21000*	.00544	.000	.1981	.2219
		2.00		.10667*	.00544	.000	.0948	.1185
		4.00		-.10667*	.00544	.000	-.1185	-.0948
		5.00		.07000*	.00544	.000	.0581	.0819
		6.00		.11000*	.00544	.000	.0981	.1219
	4.00	1.00		.31667*	.00544	.000	.3048	.3285
		2.00		.21333*	.00544	.000	.2015	.2252
		3.00		.10667*	.00544	.000	.0948	.1185

		5.00	.17667*	.00544	.000	.1648	.1885
		6.00	.21667*	.00544	.000	.2048	.2285
	5.00	1.00	.14000*	.00544	.000	.1281	.1519
		2.00	.03667*	.00544	.000	.0248	.0485
		3.00	-.07000*	.00544	.000	-.0819	-.0581
		4.00	-.17667*	.00544	.000	-.1885	-.1648
		6.00	.04000*	.00544	.000	.0281	.0519
		6.00	.10000*	.00544	.000	.0881	.1119
	6.00	2.00	-.00333	.00544	.552	-.0152	.0085
		3.00	-.11000*	.00544	.000	-.1219	-.0981
4.00		-.21667*	.00544	.000	-.2285	-.2048	
5.00		-.04000*	.00544	.000	-.0519	-.0281	
6.00		-.10333*	.00694	.000	-.1185	-.0882	
D	1.00	3.00	-.15333*	.00694	.000	-.1685	-.1382
		4.00	-.12333*	.00694	.000	-.1385	-.1082
		5.00	-.10333*	.00694	.000	-.1185	-.0882
		6.00	-.02000*	.00694	.014	-.0351	-.0049
		6.00	-.10333*	.00694	.000	-.1185	-.0882
	2.00	1.00	.10333*	.00694	.000	.0882	.1185
		3.00	-.05000*	.00694	.000	-.0651	-.0349
		4.00	-.02000*	.00694	.014	-.0351	-.0049
		5.00	.00000	.00694	1.000	-.0151	.0151
		6.00	.08333*	.00694	.000	.0682	.0985
	3.00	1.00	.15333*	.00694	.000	.1382	.1685
		2.00	.05000*	.00694	.000	.0349	.0651
		4.00	.03000*	.00694	.001	.0149	.0451
		5.00	.05000*	.00694	.000	.0349	.0651
		6.00	.13333*	.00694	.000	.1182	.1485
	4.00	1.00	.12333*	.00694	.000	.1082	.1385
		2.00	.02000*	.00694	.014	.0049	.0351
		3.00	-.03000*	.00694	.001	-.0451	-.0149
		5.00	.02000*	.00694	.014	.0049	.0351
		6.00	.10333*	.00694	.000	.0882	.1185
	5.00	1.00	.10333*	.00694	.000	.0882	.1185
		2.00	.00000	.00694	1.000	-.0151	.0151
		3.00	-.05000*	.00694	.000	-.0651	-.0349
		4.00	-.02000*	.00694	.014	-.0351	-.0049
6.00		.08333*	.00694	.000	.0682	.0985	
6.00	1.00	.02000*	.00694	.014	.0049	.0351	
	2.00	-.08333*	.00694	.000	-.0985	-.0682	

		3.00	-.13333*	.00694	.000	-.1485	-.1182	
		4.00	-.10333*	.00694	.000	-.1185	-.0882	
		5.00	-.08333*	.00694	.000	-.0985	-.0682	
E	1.00	2.00	-.05333*	.00694	.000	-.0685	-.0382	
		3.00	-.06000*	.00694	.000	-.0751	-.0449	
		4.00	-.03333*	.00694	.000	-.0485	-.0182	
		5.00	-.00667	.00694	.356	-.0218	.0085	
		6.00	-.00333	.00694	.640	-.0185	.0118	
		2.00	1.00	.05333*	.00694	.000	.0382	.0685
			3.00	-.00667	.00694	.356	-.0218	.0085
	4.00		.02000*	.00694	.014	.0049	.0351	
	5.00		.04667*	.00694	.000	.0315	.0618	
	6.00		.05000*	.00694	.000	.0349	.0651	
	3.00	1.00	.06000*	.00694	.000	.0449	.0751	
		2.00	.00667	.00694	.356	-.0085	.0218	
		4.00	.02667*	.00694	.002	.0115	.0418	
		5.00	.05333*	.00694	.000	.0382	.0685	
		6.00	.05667*	.00694	.000	.0415	.0718	
	4.00	1.00	.03333*	.00694	.000	.0182	.0485	
		2.00	-.02000*	.00694	.014	-.0351	-.0049	
		3.00	-.02667*	.00694	.002	-.0418	-.0115	
		5.00	.02667*	.00694	.002	.0115	.0418	
		6.00	.03000*	.00694	.001	.0149	.0451	
	5.00	1.00	.00667	.00694	.356	-.0085	.0218	
		2.00	-.04667*	.00694	.000	-.0618	-.0315	
		3.00	-.05333*	.00694	.000	-.0685	-.0382	
		4.00	-.02667*	.00694	.002	-.0418	-.0115	
		6.00	.00333	.00694	.640	-.0118	.0185	
	6.00	1.00	.00333	.00694	.640	-.0118	.0185	
		2.00	-.05000*	.00694	.000	-.0651	-.0349	
		3.00	-.05667*	.00694	.000	-.0718	-.0415	
		4.00	-.03000*	.00694	.001	-.0451	-.0149	
		5.00	-.00333	.00694	.640	-.0185	.0118	

*. The mean difference is significant at the 0.05 level.

Ni - Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
A	1.00	3	13.5467	.01528	.00882	13.5087	13.5846	13.53	
	2.00	3	24.5500	.02000	.01155	24.5003	24.5997	24.53	
	3.00	3	26.5500	.01000	.00577	26.5252	26.5748	26.54	
	4.00	3	13.8300	.03000	.01732	13.7555	13.9045	13.80	
	5.00	3	14.9000	.00000	.00000	14.9000	14.9000	14.90	
	6.00	3	13.3300	.00000	.00000	13.3300	13.3300	13.33	
	Total	18	17.7844	5.70398	1.34444	14.9479	20.6210	13.33	
B	1.00	3	10.2400	.01000	.00577	10.2152	10.2648	10.23	
	2.00	3	23.6000	.43589	.25166	22.5172	24.6828	23.10	
	3.00	3	24.9500	.04000	.02309	24.8506	25.0494	24.91	
	4.00	3	10.4000	.40000	.23094	9.4063	11.3937	10.00	
	5.00	3	10.4000	.10000	.05774	10.1516	10.6484	10.30	
	6.00	3	10.8300	.01000	.00577	10.8052	10.8548	10.82	
	Total	18	15.0700	6.71531	1.58281	11.7306	18.4094	10.00	
C	1.00	3	8.3500	.01000	.00577	8.3252	8.3748	8.34	
	2.00	3	20.0000	.00000	.00000	20.0000	20.0000	20.00	
	3.00	3	14.4500	.04000	.02309	14.3506	14.5494	14.41	
	4.00	3	9.9500	.01000	.00577	9.9252	9.9748	9.94	
	5.00	3	11.4500	.10000	.05774	11.2016	11.6984	11.35	
	6.00	3	8.9867	.00577	.00333	8.9723	9.0010	8.98	
	Total	18	12.1978	4.13059	.97359	10.1437	14.2519	8.34	
D	1.00	3	7.9033	.00577	.00333	7.8890	7.9177	7.90	
	2.00	3	19.0500	.02000	.01155	19.0003	19.0997	19.03	
	3.00	3	20.0000	.00000	.00000	20.0000	20.0000	20.00	
	4.00	3	9.9500	.04000	.02309	9.8506	10.0494	9.91	
	5.00	3	8.9000	.00000	.00000	8.9000	8.9000	8.90	
	6.00	3	7.6800	.02000	.01155	7.6303	7.7297	7.66	
	Total	18	12.2472	5.35661	1.26256	9.5834	14.9110	7.66	
E	1.00	3	7.2400	.01000	.00577	7.2152	7.2648	7.23	
	2.00	3	14.4500	.10000	.05774	14.2016	14.6984	14.35	
	3.00	3	11.4500	.02000	.01155	11.4003	11.4997	11.43	
	4.00	3	8.6000	.43589	.25166	7.5172	9.6828	8.10	
	5.00	3	7.4400	.04000	.02309	7.3406	7.5394	7.40	
	6.00	3	7.6000	.30000	.17321	6.8548	8.3452	7.30	
	Total	18	9.4633	2.73096	.64369	8.1053	10.8214	7.23	

Ni - Multiple Comparisons

LSD

Dependent Variable	(I) location	(J) location	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
A	1.00	2.00	-11.00333*	.01347	.000	-11.0327	-10.9740
		3.00	-13.00333*	.01347	.000	-13.0327	-12.9740
		4.00	-.28333*	.01347	.000	-.3127	-.2540
		5.00	-1.35333*	.01347	.000	-1.3827	-1.3240
		6.00	.21667*	.01347	.000	.1873	.2460
	2.00	1.00	11.00333*	.01347	.000	10.9740	11.0327
		3.00	-2.00000*	.01347	.000	-2.0294	-1.9706
		4.00	10.72000*	.01347	.000	10.6906	10.7494
		5.00	9.65000*	.01347	.000	9.6206	9.6794
		6.00	11.22000*	.01347	.000	11.1906	11.2494
	3.00	1.00	13.00333*	.01347	.000	12.9740	13.0327
		2.00	2.00000*	.01347	.000	1.9706	2.0294
		4.00	12.72000*	.01347	.000	12.6906	12.7494
		5.00	11.65000*	.01347	.000	11.6206	11.6794
		6.00	13.22000*	.01347	.000	13.1906	13.2494
	4.00	1.00	.28333*	.01347	.000	.2540	.3127
		2.00	-10.72000*	.01347	.000	-10.7494	-10.6906
		3.00	-12.72000*	.01347	.000	-12.7494	-12.6906
		5.00	-1.07000*	.01347	.000	-1.0994	-1.0406
		6.00	.50000*	.01347	.000	.4706	.5294
	5.00	1.00	1.35333*	.01347	.000	1.3240	1.3827
		2.00	-9.65000*	.01347	.000	-9.6794	-9.6206
		3.00	-11.65000*	.01347	.000	-11.6794	-11.6206
		4.00	1.07000*	.01347	.000	1.0406	1.0994
		6.00	1.57000*	.01347	.000	1.5406	1.5994
	6.00	1.00	-.21667*	.01347	.000	-.2460	-.1873
		2.00	-11.22000*	.01347	.000	-11.2494	-11.1906
		3.00	-13.22000*	.01347	.000	-13.2494	-13.1906
		4.00	-.50000*	.01347	.000	-.5294	-.4706
		5.00	-1.57000*	.01347	.000	-1.5994	-1.5406
B	1.00	2.00	-13.36000*	.20050	.000	-13.7969	-12.9231
		3.00	-14.71000*	.20050	.000	-15.1469	-14.2731
		4.00	-.16000	.20050	.440	-.5969	.2769
		5.00	-.16000	.20050	.440	-.5969	.2769
		6.00	-.59000*	.20050	.012	-1.0269	-.1531
	2.00	1.00	13.36000*	.20050	.000	12.9231	13.7969
		3.00	-1.35000*	.20050	.000	-1.7869	-.9131
		4.00	13.20000*	.20050	.000	12.7631	13.6369
		5.00	13.20000*	.20050	.000	12.7631	13.6369

		6.00	12.77000*	.20050	.000	12.3331	13.2069
	3.00	1.00	14.71000*	.20050	.000	14.2731	15.1469
		2.00	1.35000*	.20050	.000	.9131	1.7869
		4.00	14.55000*	.20050	.000	14.1131	14.9869
		5.00	14.55000*	.20050	.000	14.1131	14.9869
		6.00	14.12000*	.20050	.000	13.6831	14.5569
		4.00	1.00	.16000	.20050	.440	-.2769
	2.00		-13.20000*	.20050	.000	-13.6369	-12.7631
	3.00		-14.55000*	.20050	.000	-14.9869	-14.1131
	5.00		.00000	.20050	1.000	-.4369	.4369
	6.00		-.43000	.20050	.053	-.8669	.0069
	5.00	1.00	.16000	.20050	.440	-.2769	.5969
		2.00	-13.20000*	.20050	.000	-13.6369	-12.7631
		3.00	-14.55000*	.20050	.000	-14.9869	-14.1131
		4.00	.00000	.20050	1.000	-.4369	.4369
		6.00	-.43000	.20050	.053	-.8669	.0069
	6.00	1.00	.59000*	.20050	.012	.1531	1.0269
		2.00	-12.77000*	.20050	.000	-13.2069	-12.3331
		3.00	-14.12000*	.20050	.000	-14.5569	-13.6831
		4.00	.43000	.20050	.053	-.0069	.8669
		5.00	.43000	.20050	.053	-.0069	.8669
C	1.00	2.00	-11.65000*	.03626	.000	-11.7290	-11.5710
		3.00	-6.10000*	.03626	.000	-6.1790	-6.0210
		4.00	-1.60000*	.03626	.000	-1.6790	-1.5210
		5.00	-3.10000*	.03626	.000	-3.1790	-3.0210
		6.00	-.63667*	.03626	.000	-.7157	-.5577
	2.00	1.00	11.65000*	.03626	.000	11.5710	11.7290
		3.00	5.55000*	.03626	.000	5.4710	5.6290
		4.00	10.05000*	.03626	.000	9.9710	10.1290
		5.00	8.55000*	.03626	.000	8.4710	8.6290
		6.00	11.01333*	.03626	.000	10.9343	11.0923
	3.00	1.00	6.10000*	.03626	.000	6.0210	6.1790
		2.00	-5.55000*	.03626	.000	-5.6290	-5.4710
		4.00	4.50000*	.03626	.000	4.4210	4.5790
		5.00	3.00000*	.03626	.000	2.9210	3.0790
		6.00	5.46333*	.03626	.000	5.3843	5.5423
	4.00	1.00	1.60000*	.03626	.000	1.5210	1.6790
		2.00	-10.05000*	.03626	.000	-10.1290	-9.9710
		3.00	-4.50000*	.03626	.000	-4.5790	-4.4210

		5.00	-1.50000*	.03626	.000	-1.5790	-1.4210
		6.00	.96333*	.03626	.000	.8843	1.0423
	5.00	1.00	3.10000*	.03626	.000	3.0210	3.1790
		2.00	-8.55000*	.03626	.000	-8.6290	-8.4710
		3.00	-3.00000*	.03626	.000	-3.0790	-2.9210
		4.00	1.50000*	.03626	.000	1.4210	1.5790
		6.00	2.46333*	.03626	.000	2.3843	2.5423
	6.00	1.00	.63667*	.03626	.000	.5577	.7157
		2.00	-11.01333*	.03626	.000	-11.0923	-10.9343
		3.00	-5.46333*	.03626	.000	-5.5423	-5.3843
4.00		-.96333*	.03626	.000	-1.0423	-.8843	
5.00		-2.46333*	.03626	.000	-2.5423	-2.3843	
D	1.00	2.00	-11.14667*	.01644	.000	-11.1825	-11.1108
		3.00	-12.09667*	.01644	.000	-12.1325	-12.0608
		4.00	-2.04667*	.01644	.000	-2.0825	-2.0108
		5.00	-.99667*	.01644	.000	-1.0325	-.9608
		6.00	.22333*	.01644	.000	.1875	.2592
	2.00	1.00	11.14667*	.01644	.000	11.1108	11.1825
		3.00	-.95000*	.01644	.000	-.9858	-.9142
		4.00	9.10000*	.01644	.000	9.0642	9.1358
		5.00	10.15000*	.01644	.000	10.1142	10.1858
		6.00	11.37000*	.01644	.000	11.3342	11.4058
	3.00	1.00	12.09667*	.01644	.000	12.0608	12.1325
		2.00	.95000*	.01644	.000	.9142	.9858
		4.00	10.05000*	.01644	.000	10.0142	10.0858
		5.00	11.10000*	.01644	.000	11.0642	11.1358
		6.00	12.32000*	.01644	.000	12.2842	12.3558
	4.00	1.00	2.04667*	.01644	.000	2.0108	2.0825
		2.00	-9.10000*	.01644	.000	-9.1358	-9.0642
		3.00	-10.05000*	.01644	.000	-10.0858	-10.0142
		5.00	1.05000*	.01644	.000	1.0142	1.0858
		6.00	2.27000*	.01644	.000	2.2342	2.3058
	5.00	1.00	.99667*	.01644	.000	.9608	1.0325
		2.00	-10.15000*	.01644	.000	-10.1858	-10.1142
		3.00	-11.10000*	.01644	.000	-11.1358	-11.0642
		4.00	-1.05000*	.01644	.000	-1.0858	-1.0142
		6.00	1.22000*	.01644	.000	1.1842	1.2558
	6.00	1.00	-.22333*	.01644	.000	-.2592	-.1875
		2.00	-11.37000*	.01644	.000	-11.4058	-11.3342

		3.00	-12.32000*	.01644	.000	-12.3558	-12.2842
		4.00	-2.27000*	.01644	.000	-2.3058	-2.2342
		5.00	-1.22000*	.01644	.000	-1.2558	-1.1842
E	1.00	2.00	-7.21000*	.18015	.000	-7.6025	-6.8175
		3.00	-4.21000*	.18015	.000	-4.6025	-3.8175
		4.00	-1.36000*	.18015	.000	-1.7525	-.9675
		5.00	-.20000	.18015	.289	-.5925	.1925
		6.00	-.36000	.18015	.069	-.7525	.0325
		2.00	1.00	7.21000*	.18015	.000	6.8175
	3.00		3.00000*	.18015	.000	2.6075	3.3925
	4.00		5.85000*	.18015	.000	5.4575	6.2425
	5.00		7.01000*	.18015	.000	6.6175	7.4025
	6.00		6.85000*	.18015	.000	6.4575	7.2425
	3.00	1.00	4.21000*	.18015	.000	3.8175	4.6025
		2.00	-3.00000*	.18015	.000	-3.3925	-2.6075
		4.00	2.85000*	.18015	.000	2.4575	3.2425
		5.00	4.01000*	.18015	.000	3.6175	4.4025
		6.00	3.85000*	.18015	.000	3.4575	4.2425
	4.00	1.00	1.36000*	.18015	.000	.9675	1.7525
		2.00	-5.85000*	.18015	.000	-6.2425	-5.4575
		3.00	-2.85000*	.18015	.000	-3.2425	-2.4575
		5.00	1.16000*	.18015	.000	.7675	1.5525
		6.00	1.00000*	.18015	.000	.6075	1.3925
	5.00	1.00	.20000	.18015	.289	-.1925	.5925
		2.00	-7.01000*	.18015	.000	-7.4025	-6.6175
		3.00	-4.01000*	.18015	.000	-4.4025	-3.6175
		4.00	-1.16000*	.18015	.000	-1.5525	-.7675
		6.00	-.16000	.18015	.392	-.5525	.2325
	6.00	1.00	.36000	.18015	.069	-.0325	.7525
		2.00	-6.85000*	.18015	.000	-7.2425	-6.4575
		3.00	-3.85000*	.18015	.000	-4.2425	-3.4575
		4.00	-1.00000*	.18015	.000	-1.3925	-.6075
		5.00	.16000	.18015	.392	-.2325	.5525

*. The mean difference is significant at the 0.05 level.

Cd - Descriptives									
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
A	1.00	3	.3300	.02646	.01528	.2643	.3957	.30	.35
	2.00	3	.4100	.01000	.00577	.3852	.4348	.40	.42
	3.00	3	.4900	.01000	.00577	.4652	.5148	.48	.50
	4.00	3	.6833	.10408	.06009	.4248	.9419	.60	.80
	5.00	3	.5233	.01528	.00882	.4854	.5613	.51	.54
	6.00	3	.8000	.10000	.05774	.5516	1.0484	.70	.90
	Total	18	.5394	.17145	.04041	.4542	.6247	.30	.90
B	1.00	3	.2333	.02887	.01667	.1616	.3050	.20	.25
	2.00	3	.2800	.01000	.00577	.2552	.3048	.27	.29
	3.00	3	.4100	.01000	.00577	.3852	.4348	.40	.42
	4.00	3	.7000	.10000	.05774	.4516	.9484	.60	.80
	5.00	3	.4533	.00577	.00333	.4390	.4677	.45	.46
	6.00	3	.6500	.00000	.00000	.6500	.6500	.65	.65
	Total	18	.4544	.18176	.04284	.3641	.5448	.20	.80
C	1.00	3	.1000	.00000	.00000	.1000	.1000	.10	.10
	2.00	3	.2033	.00577	.00333	.1890	.2177	.20	.21
	3.00	3	.3100	.01000	.00577	.2852	.3348	.30	.32
	4.00	3	.4167	.00577	.00333	.4023	.4310	.41	.42
	5.00	3	.2400	.01000	.00577	.2152	.2648	.23	.25
	6.00	3	.2000	.00000	.00000	.2000	.2000	.20	.20
	Total	18	.2450	.10176	.02399	.1944	.2956	.10	.42
D	1.00	3	.1000	.00000	.00000	.1000	.1000	.10	.10
	2.00	3	.2033	.00577	.00333	.1890	.2177	.20	.21
	3.00	3	.2533	.00577	.00333	.2390	.2677	.25	.26
	4.00	3	.2233	.01528	.00882	.1854	.2613	.21	.24
	5.00	3	.2033	.00577	.00333	.1890	.2177	.20	.21
	6.00	3	.1200	.01000	.00577	.0952	.1448	.11	.13
	Total	18	.1839	.05720	.01348	.1554	.2123	.10	.26
E	1.00	3	.1000	.00000	.00000	.1000	.1000	.10	.10
	2.00	3	.1533	.00577	.00333	.1390	.1677	.15	.16
	3.00	3	.1600	.01000	.00577	.1352	.1848	.15	.17
	4.00	3	.1333	.01155	.00667	.1046	.1620	.12	.14
	5.00	3	.1067	.01155	.00667	.0780	.1354	.10	.12
	6.00	3	.1033	.00577	.00333	.0890	.1177	.10	.11
	Total	18	.1261	.02593	.00611	.1132	.1390	.10	.17

Cr - Descriptives									
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
A	1.00	3	.7800	.01000	.00577	.7552	.8048	.77	.79
	2.00	3	2.2600	.15620	.09018	1.8720	2.6480	2.16	2.44
	3.00	3	2.9367	.01528	.00882	2.8987	2.9746	2.92	2.95
	4.00	3	1.9167	.01155	.00667	1.8880	1.9454	1.91	1.93
	5.00	3	1.4000	.10000	.05774	1.1516	1.6484	1.30	1.50
	6.00	3	1.0500	.04000	.02309	.9506	1.1494	1.01	1.09
	Total	18	1.7239	.75961	.17904	1.3461	2.1016	.77	2.95
B	1.00	3	.6900	.01000	.00577	.6652	.7148	.68	.70
	2.00	3	1.9800	.01000	.00577	1.9552	2.0048	1.97	1.99
	3.00	3	1.8300	.01000	.00577	1.8052	1.8548	1.82	1.84
	4.00	3	1.8100	.01000	.00577	1.7852	1.8348	1.80	1.82
	5.00	3	1.1100	.01000	.00577	1.0852	1.1348	1.10	1.12
	6.00	3	.7733	.04933	.02848	.6508	.8959	.74	.83
	Total	18	1.3656	.54208	.12777	1.0960	1.6351	.68	1.99
C	1.00	3	.4400	.03000	.01732	.3655	.5145	.41	.47
	2.00	3	.8733	.01155	.00667	.8446	.9020	.86	.88
	3.00	3	1.4000	.10000	.05774	1.1516	1.6484	1.30	1.50
	4.00	3	.8400	.10000	.05774	.5916	1.0884	.74	.94
	5.00	3	1.4000	.20000	.11547	.9032	1.8968	1.20	1.60
	6.00	3	.5567	.01155	.00667	.5280	.5854	.55	.57
	Total	18	.9183	.39240	.09249	.7232	1.1135	.41	1.60
D	1.00	3	.3500	.10000	.05774	.1016	.5984	.25	.45
	2.00	3	.8067	.01528	.00882	.7687	.8446	.79	.82
	3.00	3	.8400	.01000	.00577	.8152	.8648	.83	.85
	4.00	3	.5600	.10000	.05774	.3116	.8084	.46	.66
	5.00	3	.7000	.10000	.05774	.4516	.9484	.60	.80
	6.00	3	.5600	.10000	.05774	.3116	.8084	.46	.66
	Total	18	.6361	.18554	.04373	.5438	.7284	.25	.85
E	1.00	3	.3100	.01000	.00577	.2852	.3348	.30	.32
	2.00	3	.7900	.10000	.05774	.5416	1.0384	.69	.89
	3.00	3	.7000	.10000	.05774	.4516	.9484	.60	.80
	4.00	3	.4900	.01000	.00577	.4652	.5148	.48	.50
	5.00	3	.5600	.04000	.02309	.4606	.6594	.52	.60
	6.00	3	.4400	.10000	.05774	.1916	.6884	.34	.54
	Total	18	.5483	.17557	.04138	.4610	.6356	.30	.89

Cr - Multiple Comparisons

LSD

Dependent Variable	(I) Location	(J) Location	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
A	1.00	2.00	-1.48000*	.06365	.000	-1.6187	-1.3413
		3.00	-2.15667*	.06365	.000	-2.2954	-2.0180
		4.00	-1.13667*	.06365	.000	-1.2754	-.9980
		5.00	-.62000*	.06365	.000	-.7587	-.4813
		6.00	-.27000*	.06365	.001	-.4087	-.1313
	2.00	1.00	1.48000*	.06365	.000	1.3413	1.6187
		3.00	-.67667*	.06365	.000	-.8154	-.5380
		4.00	.34333*	.06365	.000	.2046	.4820
		5.00	.86000*	.06365	.000	.7213	.9987
		6.00	1.21000*	.06365	.000	1.0713	1.3487
	3.00	1.00	2.15667*	.06365	.000	2.0180	2.2954
		2.00	.67667*	.06365	.000	.5380	.8154
		4.00	1.02000*	.06365	.000	.8813	1.1587
		5.00	1.53667*	.06365	.000	1.3980	1.6754
		6.00	1.88667*	.06365	.000	1.7480	2.0254
	4.00	1.00	1.13667*	.06365	.000	.9980	1.2754
		2.00	-.34333*	.06365	.000	-.4820	-.2046
		3.00	-1.02000*	.06365	.000	-1.1587	-.8813
		5.00	.51667*	.06365	.000	.3780	.6554
		6.00	.86667*	.06365	.000	.7280	1.0054
	5.00	1.00	.62000*	.06365	.000	.4813	.7587
		2.00	-.86000*	.06365	.000	-.9987	-.7213
		3.00	-1.53667*	.06365	.000	-1.6754	-1.3980
		4.00	-.51667*	.06365	.000	-.6554	-.3780
		6.00	.35000*	.06365	.000	.2113	.4887
	6.00	1.00	.27000*	.06365	.001	.1313	.4087
		2.00	-1.21000*	.06365	.000	-1.3487	-1.0713
		3.00	-1.88667*	.06365	.000	-2.0254	-1.7480
		4.00	-.86667*	.06365	.000	-1.0054	-.7280
		5.00	-.35000*	.06365	.000	-.4887	-.2113
B	1.00	2.00	-1.29000*	.01805	.000	-1.3293	-1.2507
		3.00	-1.14000*	.01805	.000	-1.1793	-1.1007
		4.00	-1.12000*	.01805	.000	-1.1593	-1.0807
		5.00	-.42000*	.01805	.000	-.4593	-.3807
		6.00	-.08333*	.01805	.001	-.1227	-.0440
	2.00	1.00	1.29000*	.01805	.000	1.2507	1.3293
		3.00	.15000*	.01805	.000	.1107	.1893
		4.00	.17000*	.01805	.000	.1307	.2093
		5.00	.87000*	.01805	.000	.8307	.9093

		6.00	1.20667*	.01805	.000	1.1673	1.2460
	3.00	1.00	1.14000*	.01805	.000	1.1007	1.1793
		2.00	-.15000*	.01805	.000	-.1893	-.1107
		4.00	.02000	.01805	.290	-.0193	.0593
		5.00	.72000*	.01805	.000	.6807	.7593
		6.00	1.05667*	.01805	.000	1.0173	1.0960
		4.00	1.00	1.12000*	.01805	.000	1.0807
	2.00		-.17000*	.01805	.000	-.2093	-.1307
	3.00		-.02000	.01805	.290	-.0593	.0193
	5.00		.70000*	.01805	.000	.6607	.7393
	6.00		1.03667*	.01805	.000	.9973	1.0760
	5.00	1.00	.42000*	.01805	.000	.3807	.4593
		2.00	-.87000*	.01805	.000	-.9093	-.8307
		3.00	-.72000*	.01805	.000	-.7593	-.6807
		4.00	-.70000*	.01805	.000	-.7393	-.6607
		6.00	.33667*	.01805	.000	.2973	.3760
	6.00	1.00	.08333*	.01805	.001	.0440	.1227
		2.00	-1.20667*	.01805	.000	-1.2460	-1.1673
		3.00	-1.05667*	.01805	.000	-1.0960	-1.0173
		4.00	-1.03667*	.01805	.000	-1.0760	-.9973
		5.00	-.33667*	.01805	.000	-.3760	-.2973
C	1.00	2.00	-.43333*	.08244	.000	-.6130	-.2537
		3.00	-.96000*	.08244	.000	-1.1396	-.7804
		4.00	-.40000*	.08244	.000	-.5796	-.2204
		5.00	-.96000*	.08244	.000	-1.1396	-.7804
		6.00	-.11667	.08244	.182	-.2963	.0630
		2.00	1.00	.43333*	.08244	.000	.2537
	3.00		-.52667*	.08244	.000	-.7063	-.3470
	4.00		.03333	.08244	.693	-.1463	.2130
	5.00		-.52667*	.08244	.000	-.7063	-.3470
	6.00		.31667*	.08244	.002	.1370	.4963
	3.00	1.00	.96000*	.08244	.000	.7804	1.1396
		2.00	.52667*	.08244	.000	.3470	.7063
		4.00	.56000*	.08244	.000	.3804	.7396
		5.00	.00000	.08244	1.000	-.1796	.1796
		6.00	.84333*	.08244	.000	.6637	1.0230
	4.00	1.00	.40000*	.08244	.000	.2204	.5796
		2.00	-.03333	.08244	.693	-.2130	.1463
		3.00	-.56000*	.08244	.000	-.7396	-.3804

		5.00	-.56000*	.08244	.000	-.7396	-.3804
		6.00	.28333*	.08244	.005	.1037	.4630
	5.00	1.00	.96000*	.08244	.000	.7804	1.1396
		2.00	.52667*	.08244	.000	.3470	.7063
		3.00	.00000	.08244	1.000	-.1796	.1796
		4.00	.56000*	.08244	.000	.3804	.7396
		6.00	.84333*	.08244	.000	.6637	1.0230
		6.00	1.00	.08244	.000	.6637	1.0230
	6.00	1.00	.11667	.08244	.182	-.0630	.2963
		2.00	-.31667*	.08244	.002	-.4963	-.1370
		3.00	-.84333*	.08244	.000	-1.0230	-.6637
		4.00	-.28333*	.08244	.005	-.4630	-.1037
		5.00	-.84333*	.08244	.000	-1.0230	-.6637
	D	1.00	2.00	-.45667*	.06694	.000	-.6025
3.00			-.49000*	.06694	.000	-.6359	-.3441
4.00			-.21000*	.06694	.009	-.3559	-.0641
5.00			-.35000*	.06694	.000	-.4959	-.2041
6.00			-.21000*	.06694	.009	-.3559	-.0641
2.00		1.00	.45667*	.06694	.000	.3108	.6025
		3.00	-.03333	.06694	.628	-.1792	.1125
		4.00	.24667*	.06694	.003	.1008	.3925
		5.00	.10667	.06694	.137	-.0392	.2525
		6.00	.24667*	.06694	.003	.1008	.3925
3.00		1.00	.49000*	.06694	.000	.3441	.6359
		2.00	.03333	.06694	.628	-.1125	.1792
		4.00	.28000*	.06694	.001	.1341	.4259
		5.00	.14000	.06694	.058	-.0059	.2859
		6.00	.28000*	.06694	.001	.1341	.4259
4.00		1.00	.21000*	.06694	.009	.0641	.3559
		2.00	-.24667*	.06694	.003	-.3925	-.1008
		3.00	-.28000*	.06694	.001	-.4259	-.1341
		5.00	-.14000	.06694	.058	-.2859	.0059
		6.00	.00000	.06694	1.000	-.1459	.1459
5.00		1.00	.35000*	.06694	.000	.2041	.4959
		2.00	-.10667	.06694	.137	-.2525	.0392
		3.00	-.14000	.06694	.058	-.2859	.0059
		4.00	.14000	.06694	.058	-.0059	.2859
		6.00	.14000	.06694	.058	-.0059	.2859
6.00		1.00	.21000*	.06694	.009	.0641	.3559
		2.00	-.24667*	.06694	.003	-.3925	-.1008

		3.00	-.28000*	.06694	.001	-.4259	-.1341	
		4.00	.00000	.06694	1.000	-.1459	.1459	
		5.00	-.14000	.06694	.058	-.2859	.0059	
E	1.00	2.00	-.48000*	.05944	.000	-.6095	-.3505	
		3.00	-.39000*	.05944	.000	-.5195	-.2605	
		4.00	-.18000*	.05944	.011	-.3095	-.0505	
		5.00	-.25000*	.05944	.001	-.3795	-.1205	
		6.00	-.13000*	.05944	.049	-.2595	-.0005	
		2.00	1.00	.48000*	.05944	.000	.3505	.6095
			3.00	.09000	.05944	.156	-.0395	.2195
	4.00		.30000*	.05944	.000	.1705	.4295	
	5.00		.23000*	.05944	.002	.1005	.3595	
	6.00		.35000*	.05944	.000	.2205	.4795	
	3.00	1.00	.39000*	.05944	.000	.2605	.5195	
		2.00	-.09000	.05944	.156	-.2195	.0395	
		4.00	.21000*	.05944	.004	.0805	.3395	
		5.00	.14000*	.05944	.036	.0105	.2695	
		6.00	.26000*	.05944	.001	.1305	.3895	
	4.00	1.00	.18000*	.05944	.011	.0505	.3095	
		2.00	-.30000*	.05944	.000	-.4295	-.1705	
		3.00	-.21000*	.05944	.004	-.3395	-.0805	
		5.00	-.07000	.05944	.262	-.1995	.0595	
		6.00	.05000	.05944	.417	-.0795	.1795	
	5.00	1.00	.25000*	.05944	.001	.1205	.3795	
		2.00	-.23000*	.05944	.002	-.3595	-.1005	
		3.00	-.14000*	.05944	.036	-.2695	-.0105	
		4.00	.07000	.05944	.262	-.0595	.1995	
		6.00	.12000	.05944	.066	-.0095	.2495	
	6.00	1.00	.13000*	.05944	.049	.0005	.2595	
		2.00	-.35000*	.05944	.000	-.4795	-.2205	
		3.00	-.26000*	.05944	.001	-.3895	-.1305	
		4.00	-.05000	.05944	.417	-.1795	.0795	
		5.00	-.12000	.05944	.066	-.2495	.0095	

*. The mean difference is significant at the 0.05 level.

Pb - Descriptives

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum	
					Lower Bound	Upper Bound			
A	1.00	3	1.0600	.02000	.01155	1.0103	1.1097	1.04	1.08
	2.00	3	2.6500	.10000	.05774	2.4016	2.8984	2.55	2.75
	3.00	3	1.8200	.02000	.01155	1.7703	1.8697	1.80	1.84
	4.00	3	2.5100	.01000	.00577	2.4852	2.5348	2.50	2.52
	5.00	3	1.8200	.01000	.00577	1.7952	1.8448	1.81	1.83
	6.00	3	1.2700	.10000	.05774	1.0216	1.5184	1.17	1.37
	Total	18	1.8550	.60173	.14183	1.5558	2.1542	1.04	2.75
B	1.00	3	1.0167	.00577	.00333	1.0023	1.0310	1.01	1.02
	2.00	3	1.7400	.10000	.05774	1.4916	1.9884	1.64	1.84
	3.00	3	.4100	.01000	.00577	.3852	.4348	.40	.42
	4.00	3	1.0400	.01000	.00577	1.0152	1.0648	1.03	1.05
	5.00	3	1.3200	.02000	.01155	1.2703	1.3697	1.30	1.34
	6.00	3	1.0400	.00000	.00000	1.0400	1.0400	1.04	1.04
	Total	18	1.0944	.41056	.09677	.8903	1.2986	.40	1.84
C	1.00	3	1.0267	.01528	.00882	.9887	1.0646	1.01	1.04
	2.00	3	1.0400	.01000	.00577	1.0152	1.0648	1.03	1.05
	3.00	3	2.5800	.02000	.01155	2.5303	2.6297	2.56	2.60
	4.00	3	.9400	.04000	.02309	.8406	1.0394	.90	.98
	5.00	3	1.1100	.01000	.00577	1.0852	1.1348	1.10	1.12
	6.00	3	.7067	.55157	.31845	-.6635	2.0769	.07	1.04
	Total	18	1.2339	.66111	.15582	.9051	1.5626	.07	2.60
D	1.00	3	.6033	.00577	.00333	.5890	.6177	.60	.61
	2.00	3	.7800	.02000	.01155	.7303	.8297	.76	.80
	3.00	3	1.6200	.10000	.05774	1.3716	1.8684	1.52	1.72
	4.00	3	.6800	.01000	.00577	.6552	.7048	.67	.69
	5.00	3	1.0400	.01000	.00577	1.0152	1.0648	1.03	1.05
	6.00	3	.6300	.03000	.01732	.5555	.7045	.60	.66
	Total	18	.8922	.36839	.08683	.7090	1.0754	.60	1.72
E	1.00	3	.5133	.01528	.00882	.4754	.5513	.50	.53
	2.00	3	.7900	.01000	.00577	.7652	.8148	.78	.80
	3.00	3	1.2500	.10000	.05774	1.0016	1.4984	1.15	1.35
	4.00	3	.6067	.01155	.00667	.5780	.6354	.60	.62
	5.00	3	.6467	.00577	.00333	.6323	.6610	.64	.65
	6.00	3	.5367	.01528	.00882	.4987	.5746	.52	.55
	Total	18	.7239	.26147	.06163	.5939	.8539	.50	1.35

Pb - Multiple Comparisons

LSD

Dependent Variable	(I) Location	(J) Location	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
A	1.00	2.00	-1.59000*	.04830	.000	-1.6952	-1.4848
		3.00	-.76000*	.04830	.000	-.8652	-.6548
		4.00	-1.45000*	.04830	.000	-1.5552	-1.3448
		5.00	-.76000*	.04830	.000	-.8652	-.6548
		6.00	-.21000*	.04830	.001	-.3152	-.1048
	2.00	1.00	1.59000*	.04830	.000	1.4848	1.6952
		3.00	.83000*	.04830	.000	.7248	.9352
		4.00	.14000*	.04830	.013	.0348	.2452
		5.00	.83000*	.04830	.000	.7248	.9352
		6.00	1.38000*	.04830	.000	1.2748	1.4852
	3.00	1.00	.76000*	.04830	.000	.6548	.8652
		2.00	-.83000*	.04830	.000	-.9352	-.7248
		4.00	-.69000*	.04830	.000	-.7952	-.5848
		5.00	.00000	.04830	1.000	-.1052	.1052
		6.00	.55000*	.04830	.000	.4448	.6552
	4.00	1.00	1.45000*	.04830	.000	1.3448	1.5552
		2.00	-.14000*	.04830	.013	-.2452	-.0348
		3.00	.69000*	.04830	.000	.5848	.7952
		5.00	.69000*	.04830	.000	.5848	.7952
		6.00	1.24000*	.04830	.000	1.1348	1.3452
	5.00	1.00	.76000*	.04830	.000	.6548	.8652
		2.00	-.83000*	.04830	.000	-.9352	-.7248
		3.00	.00000	.04830	1.000	-.1052	.1052
		4.00	-.69000*	.04830	.000	-.7952	-.5848
		6.00	.55000*	.04830	.000	.4448	.6552
	6.00	1.00	.21000*	.04830	.001	.1048	.3152
		2.00	-1.38000*	.04830	.000	-1.4852	-1.2748
		3.00	-.55000*	.04830	.000	-.6552	-.4448
		4.00	-1.24000*	.04830	.000	-1.3452	-1.1348
		5.00	-.55000*	.04830	.000	-.6552	-.4448
B	1.00	2.00	-.72333*	.03437	.000	-.7982	-.6484
		3.00	.60667*	.03437	.000	.5318	.6816
		4.00	-.02333	.03437	.510	-.0982	.0516
		5.00	-.30333*	.03437	.000	-.3782	-.2284
		6.00	-.02333	.03437	.510	-.0982	.0516
	2.00	1.00	.72333*	.03437	.000	.6484	.7982
		3.00	1.33000*	.03437	.000	1.2551	1.4049
		4.00	.70000*	.03437	.000	.6251	.7749
		5.00	.42000*	.03437	.000	.3451	.4949

		6.00	.70000*	.03437	.000	.6251	.7749
	3.00	1.00	-.60667*	.03437	.000	-.6816	-.5318
		2.00	-1.33000*	.03437	.000	-1.4049	-1.2551
		4.00	-.63000*	.03437	.000	-.7049	-.5551
		5.00	-.91000*	.03437	.000	-.9849	-.8351
		6.00	-.63000*	.03437	.000	-.7049	-.5551
		4.00	1.00	.02333	.03437	.510	-.0516
	2.00		-.70000*	.03437	.000	-.7749	-.6251
	3.00		.63000*	.03437	.000	.5551	.7049
	5.00		-.28000*	.03437	.000	-.3549	-.2051
	6.00		.00000	.03437	1.000	-.0749	.0749
	5.00	1.00	.30333*	.03437	.000	.2284	.3782
		2.00	-.42000*	.03437	.000	-.4949	-.3451
		3.00	.91000*	.03437	.000	.8351	.9849
		4.00	.28000*	.03437	.000	.2051	.3549
		6.00	.28000*	.03437	.000	.2051	.3549
	6.00	1.00	.02333	.03437	.510	-.0516	.0982
		2.00	-.70000*	.03437	.000	-.7749	-.6251
		3.00	.63000*	.03437	.000	.5551	.7049
		4.00	.00000	.03437	1.000	-.0749	.0749
		5.00	-.28000*	.03437	.000	-.3549	-.2051
C	1.00	2.00	-.01333	.18459	.944	-.4155	.3889
		3.00	-1.55333*	.18459	.000	-1.9555	-1.1511
		4.00	.08667	.18459	.647	-.3155	.4889
		5.00	-.08333	.18459	.660	-.4855	.3189
		6.00	.32000	.18459	.109	-.0822	.7222
	2.00	1.00	.01333	.18459	.944	-.3889	.4155
		3.00	-1.54000*	.18459	.000	-1.9422	-1.1378
		4.00	.10000	.18459	.598	-.3022	.5022
		5.00	-.07000	.18459	.711	-.4722	.3322
		6.00	.33333	.18459	.096	-.0689	.7355
	3.00	1.00	1.55333*	.18459	.000	1.1511	1.9555
		2.00	1.54000*	.18459	.000	1.1378	1.9422
		4.00	1.64000*	.18459	.000	1.2378	2.0422
		5.00	1.47000*	.18459	.000	1.0678	1.8722
		6.00	1.87333*	.18459	.000	1.4711	2.2755
	4.00	1.00	-.08667	.18459	.647	-.4889	.3155
		2.00	-.10000	.18459	.598	-.5022	.3022
		3.00	-1.64000*	.18459	.000	-2.0422	-1.2378

		5.00	-17000	.18459	.375	-.5722	.2322
		6.00	.23333	.18459	.230	-.1689	.6355
	5.00	1.00	.08333	.18459	.660	-.3189	.4855
		2.00	.07000	.18459	.711	-.3322	.4722
		3.00	-1.47000*	.18459	.000	-1.8722	-1.0678
		4.00	.17000	.18459	.375	-.2322	.5722
		6.00	.40333*	.18459	.049	.0011	.8055
	6.00	1.00	-.32000	.18459	.109	-.7222	.0822
		2.00	-.33333	.18459	.096	-.7355	.0689
		3.00	-1.87333*	.18459	.000	-2.2755	-1.4711
4.00		-.23333	.18459	.230	-.6355	.1689	
5.00		-.40333*	.18459	.049	-.8055	-.0011	
D	1.00	2.00	-.17667*	.03580	.000	-.2547	-.0987
		3.00	-1.01667*	.03580	.000	-1.0947	-.9387
		4.00	-.07667	.03580	.053	-.1547	.0013
		5.00	-.43667*	.03580	.000	-.5147	-.3587
		6.00	-.02667	.03580	.471	-.1047	.0513
	2.00	1.00	.17667*	.03580	.000	.0987	.2547
		3.00	-.84000*	.03580	.000	-.9180	-.7620
		4.00	.10000*	.03580	.016	.0220	.1780
		5.00	-.26000*	.03580	.000	-.3380	-.1820
		6.00	.15000*	.03580	.001	.0720	.2280
	3.00	1.00	1.01667*	.03580	.000	.9387	1.0947
		2.00	.84000*	.03580	.000	.7620	.9180
		4.00	.94000*	.03580	.000	.8620	1.0180
		5.00	.58000*	.03580	.000	.5020	.6580
		6.00	.99000*	.03580	.000	.9120	1.0680
	4.00	1.00	.07667	.03580	.053	-.0013	.1547
		2.00	-.10000*	.03580	.016	-.1780	-.0220
		3.00	-.94000*	.03580	.000	-1.0180	-.8620
		5.00	-.36000*	.03580	.000	-.4380	-.2820
		6.00	.05000	.03580	.188	-.0280	.1280
	5.00	1.00	.43667*	.03580	.000	.3587	.5147
		2.00	.26000*	.03580	.000	.1820	.3380
		3.00	-.58000*	.03580	.000	-.6580	-.5020
		4.00	.36000*	.03580	.000	.2820	.4380
		6.00	.41000*	.03580	.000	.3320	.4880
	6.00	1.00	.02667	.03580	.471	-.0513	.1047
		2.00	-.15000*	.03580	.001	-.2280	-.0720

		3.00	-.99000*	.03580	.000	-1.0680	-.9120	
		4.00	-.05000	.03580	.188	-.1280	.0280	
		5.00	-.41000*	.03580	.000	-.4880	-.3320	
E	1.00	2.00	-.27667*	.03453	.000	-.3519	-.2014	
		3.00	-.73667*	.03453	.000	-.8119	-.6614	
		4.00	-.09333*	.03453	.019	-.1686	-.0181	
		5.00	-.13333*	.03453	.002	-.2086	-.0581	
		6.00	-.02333	.03453	.512	-.0986	.0519	
		2.00	1.00	.27667*	.03453	.000	.2014	.3519
			3.00	-.46000*	.03453	.000	-.5352	-.3848
	4.00		.18333*	.03453	.000	.1081	.2586	
	5.00		.14333*	.03453	.001	.0681	.2186	
	6.00		.25333*	.03453	.000	.1781	.3286	
	3.00	1.00	.73667*	.03453	.000	.6614	.8119	
		2.00	.46000*	.03453	.000	.3848	.5352	
		4.00	.64333*	.03453	.000	.5681	.7186	
		5.00	.60333*	.03453	.000	.5281	.6786	
		6.00	.71333*	.03453	.000	.6381	.7886	
	4.00	1.00	.09333*	.03453	.019	.0181	.1686	
		2.00	-.18333*	.03453	.000	-.2586	-.1081	
		3.00	-.64333*	.03453	.000	-.7186	-.5681	
		5.00	-.04000	.03453	.269	-.1152	.0352	
		6.00	.07000	.03453	.065	-.0052	.1452	
	5.00	1.00	.13333*	.03453	.002	.0581	.2086	
		2.00	-.14333*	.03453	.001	-.2186	-.0681	
		3.00	-.60333*	.03453	.000	-.6786	-.5281	
		4.00	.04000	.03453	.269	-.0352	.1152	
		6.00	.11000*	.03453	.008	.0348	.1852	
	6.00	1.00	.02333	.03453	.512	-.0519	.0986	
		2.00	-.25333*	.03453	.000	-.3286	-.1781	
		3.00	-.71333*	.03453	.000	-.7886	-.6381	
		4.00	-.07000	.03453	.065	-.1452	.0052	
		5.00	-.11000*	.03453	.008	-.1852	-.0348	

*. The mean difference is significant at the 0.05 level.

Zn - Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
						A	1.00		
2.00	3	23.5400	.04000	.02309	23.4406		23.6394	23.50	23.58
3.00	3	31.3800	.10000	.05774	31.1316		31.6284	31.28	31.48
4.00	3	39.2200	.02000	.01155	39.1703		39.2697	39.20	39.24
5.00	3	25.1400	.10000	.05774	24.8916		25.3884	25.04	25.24
6.00	3	23.5400	.10000	.05774	23.2916		23.7884	23.44	23.64
Total	18	29.0333	5.79526	1.36595	26.1514		31.9152	23.44	39.24
B	1.00	3	15.6800	.10000	.05774	15.4316	15.9284	15.58	15.78
	2.00	3	23.5400	.01000	.00577	23.5152	23.5648	23.53	23.55
	3.00	3	24.1733	.49329	.28480	22.9479	25.3987	23.84	24.74
	4.00	3	37.6200	.02000	.01155	37.5703	37.6697	37.60	37.64
	5.00	3	23.5400	.10000	.05774	23.2916	23.7884	23.44	23.64
	6.00	3	23.5400	.04000	.02309	23.4406	23.6394	23.50	23.58
	Total	18	24.6822	6.67889	1.57423	21.3609	28.0036	15.58	37.64
C	1.00	3	15.6800	.02000	.01155	15.6303	15.7297	15.66	15.70
	2.00	3	2.5700	.10000	.05774	2.3216	2.8184	2.47	2.67
	3.00	3	15.6800	.01000	.00577	15.6552	15.7048	15.67	15.69
	4.00	3	34.4200	.01000	.00577	34.3952	34.4448	34.41	34.43
	5.00	3	21.3000	.20000	.11547	20.8032	21.7968	21.10	21.50
	6.00	3	20.3400	.01000	.00577	20.3152	20.3648	20.33	20.35
	Total	18	18.3317	9.70935	2.28852	13.5033	23.1600	2.47	34.43
D	1.00	3	7.8400	.01000	.00577	7.8152	7.8648	7.83	7.85
	2.00	3	20.5900	.01000	.00577	20.5652	20.6148	20.58	20.60
	3.00	3	5.3800	.10000	.05774	5.1316	5.6284	5.28	5.48
	4.00	3	23.5400	.10000	.05774	23.2916	23.7884	23.44	23.64
	5.00	3	2.6200	.10000	.05774	2.3716	2.8684	2.52	2.72
	6.00	3	16.8200	.02000	.01155	16.7703	16.8697	16.80	16.84
	Total	18	12.7983	8.14034	1.91870	8.7502	16.8464	2.52	23.64
E	1.00	3	17.4867	.02517	.01453	17.4242	17.5492	17.46	17.51
	2.00	3	19.5100	.01000	.00577	19.4852	19.5348	19.50	19.52
	3.00	3	13.9400	.04000	.02309	13.8406	14.0394	13.90	13.98
	4.00	3	15.5800	.01000	.00577	15.5552	15.6048	15.57	15.59
	5.00	3	8.4200	.02000	.01155	8.3703	8.4697	8.40	8.44
	6.00	3	5.8700	.03000	.01732	5.7955	5.9445	5.84	5.90
	Total	18	13.4678	4.98031	1.17387	10.9911	15.9444	5.84	19.52

Zn - Multiple Comparisons

LSD

Dependent Variable	(I) Location	(J) Location	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
A	1.00	2.00	7.84000*	.06000	.000	7.7093	7.9707
		3.00	.00000	.06000	1.000	-.1307	.1307
		4.00	-7.84000*	.06000	.000	-7.9707	-7.7093
		5.00	6.24000*	.06000	.000	6.1093	6.3707
		6.00	7.84000*	.06000	.000	7.7093	7.9707
	2.00	1.00	-7.84000*	.06000	.000	-7.9707	-7.7093
		3.00	-7.84000*	.06000	.000	-7.9707	-7.7093
		4.00	-15.68000*	.06000	.000	-15.8107	-15.5493
		5.00	-1.60000*	.06000	.000	-1.7307	-1.4693
		6.00	.00000	.06000	1.000	-.1307	.1307
	3.00	1.00	.00000	.06000	1.000	-.1307	.1307
		2.00	7.84000*	.06000	.000	7.7093	7.9707
		4.00	-7.84000*	.06000	.000	-7.9707	-7.7093
		5.00	6.24000*	.06000	.000	6.1093	6.3707
		6.00	7.84000*	.06000	.000	7.7093	7.9707
	4.00	1.00	7.84000*	.06000	.000	7.7093	7.9707
		2.00	15.68000*	.06000	.000	15.5493	15.8107
		3.00	7.84000*	.06000	.000	7.7093	7.9707
		5.00	14.08000*	.06000	.000	13.9493	14.2107
		6.00	15.68000*	.06000	.000	15.5493	15.8107
	5.00	1.00	-6.24000*	.06000	.000	-6.3707	-6.1093
		2.00	1.60000*	.06000	.000	1.4693	1.7307
		3.00	-6.24000*	.06000	.000	-6.3707	-6.1093
		4.00	-14.08000*	.06000	.000	-14.2107	-13.9493
		6.00	1.60000*	.06000	.000	1.4693	1.7307
	6.00	1.00	-7.84000*	.06000	.000	-7.9707	-7.7093
		2.00	.00000	.06000	1.000	-.1307	.1307
		3.00	-7.84000*	.06000	.000	-7.9707	-7.7093
		4.00	-15.68000*	.06000	.000	-15.8107	-15.5493
		5.00	-1.60000*	.06000	.000	-1.7307	-1.4693
B	1.00	2.00	-7.86000*	.17173	.000	-8.2342	-7.4858
		3.00	-8.49333*	.17173	.000	-8.8675	-8.1192
		4.00	-21.94000*	.17173	.000	-22.3142	-21.5658
		5.00	-7.86000*	.17173	.000	-8.2342	-7.4858

		6.00	-7.86000*	.17173	.000	-8.2342	-7.4858
	2.00	1.00	7.86000*	.17173	.000	7.4858	8.2342
		3.00	-.63333*	.17173	.003	-1.0075	-.2592
		4.00	-14.08000*	.17173	.000	-14.4542	-13.7058
		5.00	.00000	.17173	1.000	-.3742	.3742
		6.00	.00000	.17173	1.000	-.3742	.3742
		3.00	1.00	8.49333*	.17173	.000	8.1192
	2.00		.63333*	.17173	.003	.2592	1.0075
	4.00		-13.44667*	.17173	.000	-13.8208	-13.0725
	5.00		.63333*	.17173	.003	.2592	1.0075
	6.00		.63333*	.17173	.003	.2592	1.0075
	4.00	1.00	21.94000*	.17173	.000	21.5658	22.3142
		2.00	14.08000*	.17173	.000	13.7058	14.4542
		3.00	13.44667*	.17173	.000	13.0725	13.8208
		5.00	14.08000*	.17173	.000	13.7058	14.4542
		6.00	14.08000*	.17173	.000	13.7058	14.4542
	5.00	1.00	7.86000*	.17173	.000	7.4858	8.2342
		2.00	.00000	.17173	1.000	-.3742	.3742
		3.00	-.63333*	.17173	.003	-1.0075	-.2592
		4.00	-14.08000*	.17173	.000	-14.4542	-13.7058
		6.00	.00000	.17173	1.000	-.3742	.3742
	6.00	1.00	7.86000*	.17173	.000	7.4858	8.2342
		2.00	.00000	.17173	1.000	-.3742	.3742
		3.00	-.63333*	.17173	.003	-1.0075	-.2592
		4.00	-14.08000*	.17173	.000	-14.4542	-13.7058
		5.00	.00000	.17173	1.000	-.3742	.3742
C	1.00	2.00	13.11000*	.07506	.000	12.9465	13.2735
		3.00	.00000	.07506	1.000	-.1635	.1635
		4.00	-18.74000*	.07506	.000	-18.9035	-18.5765
		5.00	-5.62000*	.07506	.000	-5.7835	-5.4565
		6.00	-4.66000*	.07506	.000	-4.8235	-4.4965
	2.00	1.00	-13.11000*	.07506	.000	-13.2735	-12.9465
		3.00	-13.11000*	.07506	.000	-13.2735	-12.9465
		4.00	-31.85000*	.07506	.000	-32.0135	-31.6865
		5.00	-18.73000*	.07506	.000	-18.8935	-18.5665
		6.00	-17.77000*	.07506	.000	-17.9335	-17.6065
	3.00	1.00	.00000	.07506	1.000	-.1635	.1635
		2.00	13.11000*	.07506	.000	12.9465	13.2735
		4.00	-18.74000*	.07506	.000	-18.9035	-18.5765

		5.00	-5.62000*	.07506	.000	-5.7835	-5.4565
		6.00	-4.66000*	.07506	.000	-4.8235	-4.4965
	4.00	1.00	18.74000*	.07506	.000	18.5765	18.9035
		2.00	31.85000*	.07506	.000	31.6865	32.0135
		3.00	18.74000*	.07506	.000	18.5765	18.9035
		5.00	13.12000*	.07506	.000	12.9565	13.2835
		6.00	14.08000*	.07506	.000	13.9165	14.2435
		5.00	1.00	5.62000*	.07506	.000	5.4565
	2.00		18.73000*	.07506	.000	18.5665	18.8935
	3.00		5.62000*	.07506	.000	5.4565	5.7835
	4.00		-13.12000*	.07506	.000	-13.2835	-12.9565
	6.00		.96000*	.07506	.000	.7965	1.1235
	6.00	1.00	4.66000*	.07506	.000	4.4965	4.8235
		2.00	17.77000*	.07506	.000	17.6065	17.9335
		3.00	4.66000*	.07506	.000	4.4965	4.8235
		4.00	-14.08000*	.07506	.000	-14.2435	-13.9165
		5.00	-.96000*	.07506	.000	-1.1235	-.7965
	D	1.00	2.00	-12.75000*	.05831	.000	-12.8770
3.00			2.46000*	.05831	.000	2.3330	2.5870
4.00			-15.70000*	.05831	.000	-15.8270	-15.5730
5.00			5.22000*	.05831	.000	5.0930	5.3470
6.00			-8.98000*	.05831	.000	-9.1070	-8.8530
2.00		1.00	12.75000*	.05831	.000	12.6230	12.8770
		3.00	15.21000*	.05831	.000	15.0830	15.3370
		4.00	-2.95000*	.05831	.000	-3.0770	-2.8230
		5.00	17.97000*	.05831	.000	17.8430	18.0970
		6.00	3.77000*	.05831	.000	3.6430	3.8970
3.00		1.00	-2.46000*	.05831	.000	-2.5870	-2.3330
		2.00	-15.21000*	.05831	.000	-15.3370	-15.0830
		4.00	-18.16000*	.05831	.000	-18.2870	-18.0330
		5.00	2.76000*	.05831	.000	2.6330	2.8870
		6.00	-11.44000*	.05831	.000	-11.5670	-11.3130
4.00		1.00	15.70000*	.05831	.000	15.5730	15.8270
		2.00	2.95000*	.05831	.000	2.8230	3.0770
		3.00	18.16000*	.05831	.000	18.0330	18.2870
		5.00	20.92000*	.05831	.000	20.7930	21.0470
		6.00	6.72000*	.05831	.000	6.5930	6.8470
5.00		1.00	-5.22000*	.05831	.000	-5.3470	-5.0930
		2.00	-17.97000*	.05831	.000	-18.0970	-17.8430

E		3.00	-2.76000*	.05831	.000	-2.8870	-2.6330
		4.00	-20.92000*	.05831	.000	-21.0470	-20.7930
		6.00	-14.20000*	.05831	.000	-14.3270	-14.0730
	6.00	1.00	8.98000*	.05831	.000	8.8530	9.1070
		2.00	-3.77000*	.05831	.000	-3.8970	-3.6430
		3.00	11.44000*	.05831	.000	11.3130	11.5670
		4.00	-6.72000*	.05831	.000	-6.8470	-6.5930
		5.00	14.20000*	.05831	.000	14.0730	14.3270
		6.00					
	1.00	2.00	-2.02333*	.02037	.000	-2.0677	-1.9790
		3.00	3.54667*	.02037	.000	3.5023	3.5910
		4.00	1.90667*	.02037	.000	1.8623	1.9510
		5.00	9.06667*	.02037	.000	9.0223	9.1110
6.00		11.61667*	.02037	.000	11.5723	11.6610	
2.00	1.00	2.02333*	.02037	.000	1.9790	2.0677	
	3.00	5.57000*	.02037	.000	5.5256	5.6144	
	4.00	3.93000*	.02037	.000	3.8856	3.9744	
	5.00	11.09000*	.02037	.000	11.0456	11.1344	
	6.00	13.64000*	.02037	.000	13.5956	13.6844	
3.00	1.00	-3.54667*	.02037	.000	-3.5910	-3.5023	
	2.00	-5.57000*	.02037	.000	-5.6144	-5.5256	
	4.00	-1.64000*	.02037	.000	-1.6844	-1.5956	
	5.00	5.52000*	.02037	.000	5.4756	5.5644	
	6.00	8.07000*	.02037	.000	8.0256	8.1144	
4.00	1.00	-1.90667*	.02037	.000	-1.9510	-1.8623	
	2.00	-3.93000*	.02037	.000	-3.9744	-3.8856	
	3.00	1.64000*	.02037	.000	1.5956	1.6844	
	5.00	7.16000*	.02037	.000	7.1156	7.2044	
	6.00	9.71000*	.02037	.000	9.6656	9.7544	
5.00	1.00	-9.06667*	.02037	.000	-9.1110	-9.0223	
	2.00	-11.09000*	.02037	.000	-11.1344	-11.0456	
	3.00	-5.52000*	.02037	.000	-5.5644	-5.4756	
	4.00	-7.16000*	.02037	.000	-7.2044	-7.1156	
	6.00	2.55000*	.02037	.000	2.5056	2.5944	
6.00	1.00	-11.61667*	.02037	.000	-11.6610	-11.5723	
	2.00	-13.64000*	.02037	.000	-13.6844	-13.5956	
	3.00	-8.07000*	.02037	.000	-8.1144	-8.0256	
	4.00	-9.71000*	.02037	.000	-9.7544	-9.6656	
	5.00	-2.55000*	.02037	.000	-2.5944	-2.5056	

*. The mean difference is significant at the 0.05 level.

Appendix 2.

Contamination factor averages

Cu	0-15	15-30	30-45	45-60	60-75
AVRG	1.7	1.6	1.4	1.1	0.8

Mn	0-15	15-30	30-45	45-60	60-75
AVRG	0.8	1.1	1.1	1	0.9

Zn	0-15	15-30	30-45	45-60	60-75
AVRG	0.9	1.7	1.5	2.5	2.7

Ni	0-15	15-30	30-45	45-60	60-75
AVRG	1.3	1.5	1.5	1.6	1.3

Pb	0-15	15-30	30-45	45-60	60-75
AVRG	1.8	1.1	1.2	1.6	1.4

Cd	0-15	15-30	30-45	45-60	60-75
AVRG	1.7	2.1	2.7	2.1	1.3

Cr	0-15	15-30	30-45	45-60	60-75
AVRG	2.4	1.8	2.2	1.9	1.8

LPI	1.421	1.519	1.5810	1.610	1.3525
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Appendix 3.

Cluster (0-15cm)

Case Processing Summary^{a,b}

Cases					
Valid		Missing		Total	
N	Percent	N	Percent	N	Percent
6	100.0	0	.0	6	100.0

a. Squared Euclidean Distance used

b. Ward Linkage

Ward Linkage

Agglomeration Schedule

Stage	Cluster Combined		Coefficients	Stage Cluster First Appears		Next Stage
	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
1	3	4	.186	0	0	3
2	5	6	.759	0	0	5
3	1	3	1.392	0	1	4
4	1	2	2.759	3	0	5
5	1	5	13.992	4	2	0

Cluster (15-30cm)

Case Processing Summary^{a,b}

Cases					
Valid		Missing		Total	
N	Percent	N	Percent	N	Percent
6	100.0	0	.0	6	100.0

a. Squared Euclidean Distance used

b. Ward Linkage

Ward Linkage

Agglomeration Schedule

Stage	Cluster Combined		Coefficients	Stage Cluster First Appears		Next Stage
	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
1	5	6	.007	0	0	3
2	2	4	.017	0	0	4
3	1	5	.711	0	1	5
4	2	3	2.171	2	0	5
5	1	2	15.462	3	4	0

Cluster (30-45cm)

Case Processing Summary^{a,b}

Cases					
Valid		Missing		Total	
N	Percent	N	Percent	N	Percent
6	100.0	0	.0	6	100.0

- a. Squared Euclidean Distance used
- b. Ward Linkage

Ward Linkage

Agglomeration Schedule

Stage	Cluster Combined		Coefficients	Stage Cluster First Appears		Next Stage
	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
1	1	6	.140	0	0	3
2	3	4	.385	0	0	4
3	1	5	.807	1	0	5
4	2	3	1.688	0	2	5
5	1	2	10.138	3	4	0

Cluster (45-60cm)

Case Processing Summary^{a,b}

Cases					
Valid		Missing		Total	
N	Percent	N	Percent	N	Percent
6	100.0	0	.0	6	100.0

- a. Squared Euclidean Distance used
- b. Ward Linkage

Ward Linkage

Agglomeration Schedule

Stage	Cluster Combined		Coefficients	Stage Cluster First Appears		Next Stage
	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
1	1	6	.031	0	0	4
2	2	5	.107	0	0	3
3	2	3	.351	2	0	5
4	1	4	.850	1	0	5
5	1	2	10.076	4	3	0

Cluster (60-75cm)

Case Processing Summary^{a,b}

Cases					
Valid		Missing		Total	
N	Percent	N	Percent	N	Percent
6	100.0	0	.0	6	100.0

a. Squared Euclidean Distance used

b. Ward Linkage

Ward Linkage

Agglomeration Schedule

Stage	Cluster Combined		Coefficients	Stage Cluster First Appears		Next Stage
	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
1	4	6	.024	0	0	2
2	4	5	.241	1	0	5
3	1	3	.465	0	0	4
4	1	2	3.039	3	0	5
5	1	4	12.191	4	2	0