IMPACTS OF HEAVY METALS IN DUMPSITES ON SOIL AND VEGETATION IN SELECTED LOCATIONS IN KWARA STATE

BY

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04/55EI008

BEING A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF

DOCTOR OF PHILOSOPHY (Ph.D.) IN PLANT BIOLOGY (PLANT DIVERSITY AND ENVIRONMENTAL MANAGEMENT OPTION) IN THE DEPARTMENT OF PLANT BIOLOGY, FACULTY OF LIFE SCIENCES, UNIVERSITY OF ILORIN, ILORIN.

AUGUST, 2018

CERTIFICATION

I certify that the studies reported in this thesis were conducted under the supervision of Prof. P. O. Fatoba, Department of Plant Biology, University of Ilorin. The thesis has been read and accepted as meeting the requirement of the Department of Plant Biology and the University for the award of Ph.D. degree in Plant Biology (Plant Diversity and Environmental Management Option).

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_____

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DEDICATION

This research work is dedicated to God, the Alpha and Omega

ACKNOWLEDGEMENTS

I acknowledge the divine hand, love and presence of the Almighty God before, during and even after the completion of this study. He has proven in no small measure that He is an ever-faithful, never-failing and promise-keeping God. This course could not have reached this stage were it not for His grace.

On a very special note and with much heart-felt gratitude, I wholeheartedly appreciate my Supervisor, Prof. P. O. Fatoba, this work would be far from materialization without his fatherly care, patience, logical and constructive criticism, attention advice and close supervisions. He shared in my fears and apprehension, his resolute understanding, prayers and perseverance helped to calm the storm throughout the duration of this course to him am eternally grateful.

My special thanks go to my parent Mr and Mrs E.A. ADEYEMO who stood by me in the face of all odds when my strength was failing like the proverbial ”wall of Gilbraltar’’. Their encouragement and love has been the propelling force in my quest for the Golden Fleece and a better tomorrow… I am indeed grateful and I pray you live long to reap the reward of your labour in Jesus name.

My deepest regards go to my darling husband, Dr. Emmanuel Olukoyejo for his unquantifiable love, spiritual, moral and financial assistance throughout the programme and for always being my constant support in moments when I needed someone to say ‘’You Can Do It and You Will’’, and my children; Elijah Ayanfeoluwa and Elizabeth Inioluwa who have been part of this work. Their resolute understanding, prayers, love and care have made my dreams of who I am come true.

I am sincerely grateful to my siblings; Olaoye's, the Udensi's and Pharmacist Ayodeji for their incessant prayers, social, moral and financial support given to me which allayed my fears and has make this milestone a reality.

Let me express my sincere gratitude also to Dr. A. A. Abdulrahaman, the Head of the Department of Plant Biology, for his fatherly support and encouragement throughout my studies in the University of Ilorin, while also thanking other Lecturers in the Department of Plant Biology, who have impacted my life in one way or the other: Prof. E. O. Etejere, Prof. J. A. Morakinyo, Prof. F. A. Oladele (Late), Prof. O. T. Mustapha., Dr. K. S. Olorunmaiye, Mr F. O. Egbedo, Dr. C. O. Ogunkunle, Dr. B. U. Olayinka, Dr. D. Animasaun, Dr. S. Oyedeji, Dr. (Mrs) K. A. Abdulkareem, Dr. A. A. Abdullateef, Mr. G. S. Olahan, Dr. T. Garuba, Mr. S. B. Adeyemi and my colleagues Dr. Kenny, Mr. Samuel Oluwatobi, Mr. Fidelis, Mrs. Lawal, Mrs Gada and others, you all mean so much to my academic progression. I deeply appreciate you all.

I will not forget to thank the non-academic staff of the Plant Biology Department: Messrs Sunday Adebayo, Bolu Ajayi, A. O. Olawoyin, C. O. Onele and S. O. Akin, I. O. Salimon and Mr. Taiwo of Chemistry Department. You are all appreciated.

I am grateful for the immense assistance and support received from the family of Dr. and Dr (Mrs) Ajala, Dr and Dr (Mrs) Iwintolu, Pastor and Dr. (Mrs) Ewetola, The Olutimehin's, The Alakeji's, The Olatunde's, The Olanrewaju's and The Daramola's during the course of this programme. To everyone who has contributed to my fulfilment in life and this programme, but whose name were not mentioned here. You are all highly appreciated.

Finally, I am extremely grateful to all my leaders and students of Deeper Life Campus Fellowship in LAUTECH Ogbomoso and OAU Eleyele in Ile-Ife for their encouragement and

unending prayers. Your love and friendship mean the world to me. Special thanks to Mummy Olawoye for her encouragement and support at various stages of this programme.

I AM GRATEFUL TO YOU ALL, THANKS FOR BEING PART OF MY SUCCESS STORY

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ABBREVIATIONS

HM – Heavy Metals

WAP- Weeks After Planting

DS - Dumpsite Soil

BD – Biochar with Dumpsite soil

CS – Control Soil

BC – Biochar with Control soil

MB – Maize Cob-derived Biochar

MaP- Macro Pore

MiP - Micro Pore

SEM- Scanning Electron Microscopy

EDX – Energy Dispersive X-ray

FT-IR- Fourier Transform Infrared Spectroscopy

ABSTRACT

Indiscriminate dumping of refuse is one of the major sources of pollution to the environment. Clean up of these wastes has led to appearance of dumpsites which has become preferable farmlands. This study was carried out to investigate the impacts of heavy metals (HMs) in dumpsites on soil and vegetation of selected locations and the possibility of reducing the availability of heavy metals (HMs) to the plants. The objectives of the study were to: (i) assess the heavy metal concentrations in the soil and plants from the dumpsites; (ii) develop methods for production of biochar from the waste; (iii) assess the effects of biochar on the yields of *Solanum lycopersicon*, *Amaranthus esculentus*, *Corchorus olitorious*, *Abelmoschus esculentum* and *Tithonia diversifolia*; and (iv) assess the mobility potential of the biochar on the HMs in selected plants.

Plants and soil samples were collected at 10 km intervals in Oko-Olowo, Offa, Omu-Aran (Urban), and Odo-Ore, Ipee and Aran-Orin (rural). The samples were digested using Aqua regia method after which Cd, Pb, Cr, Zn, Fe and Cu concentrations were determined with Atomic Absorption Spectrophotometer (AAS). Composite dumpsite soil was used to raise the plants and its HMs content determined by AAS. Biochar was prepared by slow pyrolysis of maize cobs (MB). Scanning Electron Microscopy, Energy Dispersive X-ray and Fourier Transform Infrared were used to identify the properties of the MB. Data were analysed with Analysis of Variance and Duncan Multiple Range Test at $p < 05$.

The findings of the study were that:

i. Pb (0.00 – 75.00), Cd (0.00 – 4.00), Zn (4.50 – 1290), Ni (0.00 – 19.5), Cu (2.5 – 225) and Fe (1,390 – 20,850) mg/kg were present in the soils;

ii. Pb (0.00 – 7.00), Cd (0.00 – 0.50), Zn(16.00 – 310.00), Ni (0.00 – 5.50), Cu (1.00 – 9.50) and Fe (195.00 – 4,950.00) mg/kg were found in the plants;

iii. MB had well-defined pore structure and contained C, O, Si, K and Mg;

v. MB increased the yields of *S. lycopersicon* (50%), *C. olitorious* (6.3%), *Abelmoschus esculentum* (40.1%) and *T. diversifolia (*7.5%) but reduced the yield of *Amaranthus esculentus* (50%);

vi. there was significant reduction ($p \leq 0.05$) in the HMs content of the selected plants with MB. *Abelmoschus esculentum*, *C. olitorious*, *Amaranthus esculentus*, *T. diversifolia* and *S. lycoperscon* on dumpsite soil contained 2.78. 2.23, 2.29, 5.20, 3.50 mg/kg of Pb while those with biochar had 2.36, 0.90, 2.35, 3.67, 2.40 and 2.30 mg/kg, respectively; and

vii.*Abelmoschus esculentum* accumulated Ni, Cu and Zn but excluded Cd, Pb and Fe, *Amaranthus esculentus* accumulated Cd and Zn but excluded Pb, Ni, Cu and Fe, *T. diversifolia,*accumulated Cd, Ni and Zn, *C. olitorious* accumulated Cd and Pb while *S. lycopersicon* excluded all the investigated HMs.

The study concluded that indiscriminate dumping of waste contributed to the HMs load of dumpsite soil and vegetation. It is recommended that remediation process be put in place to reduce the HMs load in order to avert the health hazards that may result in humans that consume the vegetables.

Word Count: 495

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Solid wastes other than radioactive wastes are often referred to as household solid waste (www.epa.gov). Waste can be defined as a useless or unwanted materials discharged as a result of human activity (www.unep.gov). Most commonly waste are solid, semi-solid or liquid found in containers thrown out of the houses, commercial or industrial premises.

Waste can be classified into three different groups depending on their sources: household waste (generally termed municipal waste); industrial waste (which could be hazardous waste; and biomedical waste or hospital waste known as infectious waste) (www.environment.gov). U.S-Law-solid waste Act 2 of 1999 defined "Solid waste as any trash or slush from a waste treatment plant, water treatment plant supply or air pollution control facilities and other discarded materials including solid, liquid, semi-solid or contained gaseous materials which result from industrial, mining, and agricultural operations(www.epa.gov).

Wastes are materials or objects which are disposed off or planned to be disposed off or are expected to be disposed of by provision of national law (United Nation Environmental Programme, 2006). The global rise in human population is impacting negatively on the availability of land for farming, especially in the urban and rural settlements. Fertile lands in these settlements are being used for building and for other industrial activities. Old dumpsites have now become an ideal site for farming activities. In Nigeria, it is observed that crops planted on these sites grows better than those on the surrounding areas. Dumpsites are known to be rich in soil nutrients for plant harvest and development because decayed and composted wastes

enhance soil fertility (Ogunyemi*et al*.,2003). Dumpsites soils are also used to fill polyethylene bags and nursery pots to raise seedlings. Dumpsites especially in most third world countries account for a higher proportion (50-90%) of organic materials (Asomani-Boateng and Murray, 1999);however a considerable proportions of plastic, paper, metal rubbish and batteries which are known to be sources of metals which may be hazardous to man and his environment are also present (Alloway and Ayres, 1997; Pasquini and Alexander, 2004; Woodbury, 2005). These metals are not biodegradable and each has toxic effects impacts on living organisms at various concentration. When man is exposed to such metals, it may cause blood and bone disorders, kidney damage, decreased mental capacity and neurological damage (NIEHS, 2004).Crops accumulates whatever is present in the soil and therefore these hazardous metals are also absorbed and bioaccumulate in the stems, fruits, roots, grains and leaves of the crops (Fatoki 2000), which may finally be transferred to man in the food chain

The term disposal means the discharge, deposit, injection, dumping, spilling, leaking or placing of any solid waste or hazardous waste into or any land or water body so that such solid waste, hazardous waste or any constituent thereof may enter into the environment or be emitted into the air or discharged into any waste including ground waters from community activities (U.S Law-Solid Waste Act 2, 1999). Waste disposal is the management of waste to prevent harm to the environment, injury or long term progressive damage to health. Disposal of waste is where the purpose is to permanently store the waste for the period of its biological and chemical activities such that it is rendered incapable of being harmful (U.S Law-Solid Waste Act 2, 1999).Waste management can be referred to as the collection, transport, processing or disposal of waste materials usually the ones produced by human activities, in an effort to reduce their effects on human's health or local community (U.S Law-Solid Waste Act 2, 1999).

Waste management has always been part of human society and its study has reduced the wealth of detail over the way of life it results from. For example, paleontology relies for a good part on the study of waste (such as bone or broken utensils) to generate the knowledge we have of the pre-historic civilization. The National Solid Waste Strategy for Swaziland (2003) reported that waste management consists of water prevention, reuse, material recycle, compositing, energy recovery and final disposal. Today, unlike in previous historical period, this covers a wide variety of materials, activities, and industrial sector. As the material- wealth of household increased throughout history, generation of waste has also increased. In thousands years ago, a bone left over from a meal would be turned into a valuable tool, it is today not even given to dogs, who gets pet food; it gets "thrown away", just as many valuable items. In our society today "throwing away" is even sometimes the most convenient and cheapest ways to get rid of object that could still be of use somewhere else. It is the effect of this "thrown away" act on the environment that would be studied.

Potentially toxic metal (PTM) contamination of soil is widespread and contamination could be from geological sources or from anthropogenic sources. The sources of these PTM (e.g Cd, Cr,Pb and Zn) include soil parent material, volcanic eruption, fertilizer, pesticide, sewage sludge, power station, automobiles, incineration of waste and waste disposal, metal smelting plants, mines e.t.c (Ruley *et al*.,2006). The contamination of these toxic metals in agricultural land is a major concern. These heavy metals in soil can bioaccumulate in plants and get transferred to the food chain hence, raise human and animal health concern. Once these heavy metals are absorbed by humans and animals, it can cause adverse health effects. Pb, Cd and Cr are of concern because they are poisonous to plants and animals even in minute concentrations;

though Zn is an essential trace metals for plants and animal but can be dangerous at high concentrations (Wolnik*et al*.,1983).

What to do with this waste has been a problem to government, industries and individuals. In recent years solid waste has become a source of galloping trouble for citizen of United States and other highly developed rich nations. In 1920s, public refuse disposal service of U.S cities and town was responsible for 2.1 pounds of solid waste per day. Then during the 1970s, the wiser developed countries began to institute "polluters pays" principle in which those who are responsible for environmental pollution were charged with putting it right. This was because there was no proper solution for the management of waste (Renzoni, 2002).

Solid waste differs in composition which may be influenced by many factors such as culture, affluence, locations etc Solid waste as the management by many depends on the composition of the solid waste such as the grass composition, moisture content, average particulate size, chemical composition and density. The knowledge of these usually help in disposal plans (Sally, 2000).

In Nigeria today, urban centres are experiencing an increase rates of environmental deterioration with refuse dumped along drainage channels even the southern part of Nigeria is not an exception which is the focus of this project work. The waste disposal sites are found at the outskirt of urban area and they have turned into main contamination sites due to the incubation and proliferation of flies, mosquitoes and rodents; which are disease transmitter (vectors). The situation causes gastro intestinal, dermatological, respiratory, genetic and several other kinds of infectious diseases (Marshal, 1995). U.S Environmental Protection Agency (2006) stated that

dumping sites have a very high economic and social cost in the public health service and have not yet been estimated by government and industries.

It is very alarming today, considering the nature and composition of wastes generated, little attention is given to the proper treatment and care of the disposal sites. Municipal solid waste not only contains 'useful' and often re-usable materials (such as paper, plastic, glass, and food remains) but also contains increasing amount of harmful substances (Biwas, 1989). Typical of the latter is mercury from batteries, cadmium from fluorescent tubes, pesticides and bleaches as well as a wide range of toxic chemicals such as solvents, paints, disinfectants and wood preservatives.

Medina (2000) stated that pollution is not directly transferred from land to people, except in the case of dust and direct contact with toxic material. Pollutants disposed on land usually enter the human body through contaminated crops, animals, food product or water (Medina, 2002). Land pollution can also damage terrestrial eco-system, resulting in deterioration of the conservation and amenities values of the environment (www.epa.gov) The Environment Impact Assessments of the environment to know its heavy metal concentration in the environment have been documented (lpinmoroti *et al.*, 1970). However, the need for continued and effective monitoring of the sources and distribution of heavy metal in the environment is necessary. Most heavy metals occur at varying extent within all components of the environment, thus heavy metals' pollution of the environment does not mean usual occurrence of the metals within a component; rather than it represents the occurrence of the metals relative to the natural occurrence (Markert*et al*., 1997). Heavy metals are present in trace concentrations in the soil and vegetation, and much more prominent in solid waste containing non-biological and used products (Juste*et al*., 1992). It is observed that the problem of solid waste has become one of the

serious environmental problem facing the nation, because of its resultant impacts on the pollution of soil, water and air.

Heavy metals toxicity can cause impaired or reduced mental, central nervous function, lower energy level and damage to blood composition, lungs, kidney, liver and other neurological organs among others (Magaji, 2010). An important part of estimating the risk of health effects from exposure to toxicants involves extrapolation from experimental observation data, and identification of the hazard source is also very important. Many heavy metals act as poison biologically even at small concentrations such as parts per billion (ppb) levels. The toxic elements accumulated in the soil organic matter contents are taken up by plants growing on them (Dara, 1993). The metals are not toxic as the condensed free elements but are dangerous in the form of cations and when bonded to short chains of carbon atoms (Bairds, 1995). Many metals with important commercial uses are toxic and hence undesirable for indiscriminate release into the environment (Bunce, 1990).

There is variation in the toxic heavy metals leachate in pollutants, indication that degraded solid wastes generate very strong leachate contaminating high organic and inorganic pollutant and may contaminate the water body (Medina, 2002). Once contaminated, the cost of treating underground water and surface water is high. Moreover, the cost in term of ill health and the subsequent loss in productivity is higher. According to Medina (2002), the main models of solid waste disposal in the United States are dumping or land filling and incineration. Waste in landfill is initially degraded aerobically, using up oxygen and converting the organic matter to carbon IV oxide. After sometimes, further degradation is anaerobic during which methanogenic bacteria generate methane (www.epa.gov). Landfill gas typically contains 40% to 60% methane by volume and carbon dioxide (www.epa.gov)

Methane can be an environmental hazard by migrating from landfill either laterally or upwardly into the environment (www.foe.co.uk). At low concentrations, it can damage vegetation and cause unpleasant odours but at high concentrations, it forms explosive mixtures (www.epa.gov). The role of methane in global atmospheric changes has received increasingly attention recently. Methane from landfill contribute significantly to annual global emissions of methane (www.foe.co.uk). Methane has global warming potential up to 63 times of carbon iv oxide and accounts for about 15% of the global warming due to anthropogenic emission (www.environment-agency,gov.uk). The emissions of methane occurs when waste are disposed off in a landfill which involvesburying of waste in most countries including Nigeria (F.E.P.A, 1991).

A properly designed and well managed landfill can be a hygienic and relatively method of disposing waste materials (F.E.P.A, 1991). Poorly designed or poorly managed landfill can create a number of adverse environmental impacts such as windblow, attraction of vermin and generation of liquid leachates(www.epa.gov). Pollutants found in the leachate released into the sub-surface include organic contaminants which are soluble refuse components of decomposition products of biodegradable fraction of municipal solid waste and a variety of heavy metal (Medina, 2002).

Methane and carbon IV oxide are produced as organic waste breakdown anaerobically. Methane creates odour problem and skills surface vegetation (EI-Fadel, 1997). A large proportion of recyclable component i.e. paper, plastic, metal etc are collected by rag pickers from garbage bins, roadsides or in streets in metropolitan cities thus supplying raw materials to the flourishing recycling unit. The land fill gas from these sites can be used as substitute for fossil fuel, generating additional revenue and thus reducing pollution (www.epa.org). Lately, in the

developed world, the conversion of landfill gas into powder has become a lucrative business. Due to foul odour emanating from the landfills and explosion hazards due to emission of methane, a 1 to 2 km wide strip around the dumping site is unsuitable either for habitation or for plant life (www.epa.com). Other method of disposal is integrated waste management using Life Cycle Analysis (LCA) (www.epa.com). This attempts to offer the most benign option for waste management. For mixed waste (municipal solid waste), a number of broad studies have indicated that waste administration, source and collection followed by reused and recycling of the non-organic fraction and energy, compost/fertilizer of the organic waste fraction through an aerobic digestion seem to be favoured path (www.eea.europa.eu).

Incineration is a disposal method in which solid organic wastes are subjected to combustion so as to convert them into residues and gaseous product (www.eoa.gov). Incineration process the volume of solid wastes to 20 – 30% of the original volume. Incinerator converts waste materials into heat, gas, steam and ash (www.epa.gov). The United Nation Environment Protection Agency (2006) stated that incineration is the process of named "energy-from-waste" or "waste-to energy". This is misleading as there are other ways of recovering energy from waste which do not involve direct burning. It is recognized as practical methods of disposing hazardous waste materials such as biological and medical wastes (www.epa.gov). Many entities now refer to disposal of waste by exposure to high temperature as thermal treatment (www.epa.gov).

Waste to energy combustion or waste to wealth through combustion and recovery of useful products is a method of handling an increasing percentage of municipal waste. Waste to wealth is a very important factor in the overall integrated solid waste management strategy. The traditional term "incineration" has acquired a bad connotation in the mind of the public due to the poor operation of some waste combustors. Therefore, the term waste-to-energy combustion is now

widely used in place. The term incineration refers to modern practice of burning of waste that cannot be recycled economically (Frank and Keith, 2002). Burning of wastes has long been recognized as a final disposal solution, because the organic matter of the waste is destroyed and only solid residues remain. By comparison, the solution to this is land-filling that amounts to storage, with the continuing risk of unwanted consequences (Taylor, 1992; Jones, 1994). As of the year 2000, over 90 percent of household waste is combusted in Japan, 75% in Europe, where landfill of organic matter is essentially prohibited. In the United States, only 15 percent is combusted although in some states, it approaches 50 percent: the low cost competition of landfills has been a major factor in limiting combustion. Waste combustion results in discharge of gaseous and particulate matter to the atmosphere and causes public concern for health and the environment. In order to take advantage of combustion technology, great efforts and continuous evolution have been applied to minimize negative effects. In addition, it is necessary to dispose off the solid residues of combustion which have the potential for harm if not properly managed, mainly due to the solubility of metals, and the risk that they potentially impose on the environment. Based on 2001 data, scrap tyres represented nearly 5.7 million tons, or about 1.8 percent, of the total solid waste stream generated annually in the United States. In terms of quantity, this percentage translates to nearly 281 million waste tyres (RMA, 2002a). These in turn are part of the estimated 1.4 billion scrap tyres that are generated worldwide.

Solid waste handling and disposal are major environmental problems in many urban centres in Nigeria. In a few cases, the municipal wastes, mostly garbage and wastes from food processing industries are mainly burned or simply dumped. People that lives in the city have long advocated that any form of waste, with proper compositing and processing, can be made into fertilizers that farmers will gladly pay for. However, the modern farmer is not willing to accept this position

since he is an astute businessman who has to be convinced that the risk cost involved is small enough to benefit him (Carlson, 1976). Municipal refuse may contain paper, food wastes, metals, glass, ceramic, ashes.

Agricultural waste can be used in the production of biochar. Biochar is a product that is carbon-rich which is gotten by heating the feedstock/biomass in a closed system under limited supply of oxygen. Currently, there are several thermochemical technologies such as pyrolysis, gasification, and hydrothermal conversion to produce biochar. Pyrolysis involves the heating of organic materials in the absence of oxygen to yield a series of bioproducts: biochar, bio-oil, and syngas. Pyrolysis is a simple and inexpensive process which has been used to produce charcoal for thousands of years. However, traditional earthen and brick kilns used to produce charcoal usually vent a large amount of volatiles to the atmosphere, which causes air pollution. Modern pyrolyzers are designed to capture the volatiles for the production of bio-oil and syngas. Gasification is a thermochemical process where biomass is heated with a small amount of air to produce a main product—syngas and a by-product biochar. Hydrothermal conversion primarily focuses on using wet biomass to generate bio-oil. Biochar is a by-product of that process as well. Biochar can be used directly as a substitute for pulverized coal as a fuel. But one of major distinctions between biochar and charcoal (or char) is that the biochar is produced with the intent to be added to a soil as a means of sequestering carbon and enhancing soil quality. When used as a soil amendment, biochar has been reported to boost soil fertility and improve soil quality by raising soil pH, increasing moisture holding capacity, attracting more beneficial fungi and microbes, improving cation exchange capacity (CEC), and retaining nutrients in soil (Lehmann *et al.*, 2006; Lehmann, 2007). Another major benefit associated with the use of biochar as a soil amendment is its ability to sequester carbon from the atmosphere-biosphere pool and transfer it

to soil (Winsley, 2007; Guant and Lehmann, 2008; Laird, 2008). Biochar may persist in soil for millennia because it is very resistant to microbial decomposition and mineralization. This particular characteristic of biochar depends strongly on its properties, which is affected in turn by the condition of pyrolysis and the type of biomass/feedstock used in its production. Previous studies indicated that a bioenergy strategy that includes the use of biochar in soil not only leads to a net sequestration of CO_2 (Woolf et al., 2010), but also may decrease emissions of other more potent greenhouse gases such as N_2O and CH_4 (Spokas*et al*., 2009).

The problem of solid waste is not just that of generation nor collection but that of disposal and its effects on the quality of soils and plants. The open dumping of solid waste apart from being unsanitary and unaesthetic creates breeding space for rodents, flies, mosquitoes and other disease carrying insects(vectors). Open waste dumping, among other methods of solid waste disposal constitute serious problems and health risk (Magaji, 2005). Most of such disposal sites are not scientifically selected nor well planned, or properly managed so they are usually accessible to scavengers, animals, and vegetable cultivators.

Soil is usually the most polluted part of the ecosystem around dumpsites because the seepage around dumpsites or the seepage of water through the waste dump leaches out undesirable medium of transporting and distributing chemicals. Contaminants like heavy metals, acid mine, cyanides, radioactive substance and industrial chemicals and substances which are not only dangerous in themselves but can greatly react in a way that their total effects can always be greater than the sum of the effects taken independently with other materials (Fiar*et al.*,1968) are contained in the leacheate.These adverse impacts of dumpsites include: threat to public health, production of matters, and toxicity to plants. Illegal roadside dumping and litter near landfill, dust and windblown litters, odours, multiplication of vectors such as insects, rodents and birds

are inclusive (Lee *et al.*,1995). Lead is usually ingested through food, water and cigarettes (Krankel, 1974; Sax and Sax, 1975). Lead is very toxic and has very chronic health implications even at very low concentration (Meittinien, 1975; Bryan, 1976). Ingestion of Pb could cause mental retardation in children (Huges*et al.*, 1980), and colic anemia and renal diseases (Fischbein, 1992). Pb replaces Ca in the bone (Bryce-Smith, 1971; Mills, 1971). Its effect is cumulative and long term exposure has been noted to cause serious health hazard (Essien, 1992) which include inhibition of the synthesis of haemoglobin and also adversely affect the central and peripheral nervous system as well as the kidney (Bhata, 2002).

1.2 JUSTIFICATION OF THE STUDY

It has been noted that farmers raise vegetables on dumpsites and these plants grows well but the level of heavy metals present in these crops are always above the permissible limits and it has adverse effects on the populace Health risk due to heavy metal contamination has been widely reported (Baker et al., 2000; Claire et al., 1991; Duruibe et al., 2007). Crops and vegetables grown in soils contaminated with heavy metals have greater accumulation of heavy metals than those grown in uncontaminated soil (Eriyamremu et al., 2005).Consumption of vegetable with elevated levels of heavy metals may cause related health disorders. Crops harvested in soils of the refuse dump site presented higher levels of the metals when compared to those crops from the control sites. This is interpreted to mean that if the level of these metals in soils is significantly increased, the test crops have the potential of showing increased uptake of the Metals (Amusan et al 2005). Hence the need to assess the impacts of dumpsites on surrounding soil and plants

1.3 AIM OF THE STUDY

This research work is designed to examine the impacts of wastes dumpsites on the surrounding soil and plants.

1.4 RESEARCH OBJECTIVES

The aim will be achieved through these specific objectives stated as follows:

- **i.** Identify the major components of the wastes;
- **ii.** identify different plant species that are native to these dumpsites,
- **iii.** assess the level of uptake of these heavy metals by native plants ;
- **iv.** possibly develop methods of reducing the wastes or converting them to wealth (production of biochar / organic fertilizer);
- **v.** identify the effects of Biochar on soil simulated plants on some selected crops : okra, amaranth, tomato, *Corchorus olitorious*, and *Tithonia diversifolia* with the addition of Biochar; and
- **vi.** determine the impacts of these heavy metals on the shoots, roots and fruits of the selected crops/ plants.

CHAPTER TWO

2.1 Literature review

Recently, many studies have shown that heavy metal (metals and metalloids) with an atomic density > 6g/cm^2 - from the wastes can accumulate and persist in soils at environmental hazardous levels (Purves 1973; Carlson, 1976; Alloway, 1996). Chaney (1980) and Smith *et al.* (1996) cautioned on the use of wastes in crop production since it may be possible for heavy metal from the waste to accumulate in soils and thereby enter the food chain, contaminate surface and underground water thus cause health hazard. Lead contamination of biota is well documented (Bearington, 1975; Odukoya and Ajayi, 1987;Boon and Soltanpour, 1992).

Human being may be exposed to nickel by consuming contaminated food containing nickel. Foods naturally high in nickel include soya-beans, nuts and oat meals. Miller and Miller (2000) noted that Zn and Cu are harmful to plants before they are absorbed in sufficient concentrations to affect animals or human. Cadmium generally hinders germination of seeds (Rascio *et al*., 1993), plant growth (Greger *et al*., 1991), nutrition distribution (Moral *et al*., 1994) and photosynthesis (Krupa *et al*., 1993). It increases activity of several enzymes, e.g. glucose-6-phosphate-dehydrogenase (Van Assche *et al*., 1988) whereas activity of other enzymes are influenced differently (Karataglis *et al*., 1991). Since Cd^{2+} ions accumulate at higher levels in leaves than in other parts of plants (Marschner, 1995).

Waste handling facilities are lacking in much highly populated area in most developing and underdeveloped countries due to the lack of proper planning. This result in the discharge of household sewage and refuse into the environment untreated. Soil amended with waste have been reported to have organic matter concentration in high quantity (Anikwe, 2002). Soil organic matter influences the degree of aggregation and aggregate stability and can reduce bulk density and increase total porosity and conductivity in heavy clay soil (Anikwe, 2002).

It has been the interest of the public to know whether vegetables, fruits and food crops cultivated in polluted soils are safe for human consumption especially now that environmental quality of food production is of major concern (Chiroma *et al., 2003*). The understanding of the behaviour of heavy metal in soil-plant system seems to be particularly significant. The sources of heavy metal to plants are their growth media (air, soil, water) from which heavy metals are taken up by roots or foliage. Although, some heavy metals such as Cu, Zn, Mn, and Fe, are essential in plant nutrition, many heavy metals do not play any significant role in the plants physiology. Plants growing in a polluted environment can accumulate the toxic metals to high concentration causing serious risk to human health when consumed (Kabata-Pendias, 1984; Alloway, 1990; Vousta *et al.,* 1996).

There is considerable variability in actual uptake by plants of these elements from soil depending on the pH and organic matter content, cationic exchange capacity, binding to different soils components and the plant species involved (Kabata-Pendias and

Pendias,1984; Nyles and Ray, 1999). Heavy metals have been reported in crops grown in abandoned polluted areas (Ndiokwere, 1984; Jeanne and Sidle,1991; Ihenyen, 1991;Okoronkwo *et al*., 2005a) and also in soils irrigated with sewage water (Chiroma *et al*., 2003).

Heavy metal pollution in air, water and agricultural soil is one of the major ecological concerns due to its impact on the human food through the food chain and its high persistence in the environment. Soil contamination with the heavy metal is a global problem leading to agricultural losses and hazard health effects as metals enter the food chain. Metals from agricultural wastes, mining and smelting etc. form a natural part of terrestrial system and occur in soil, rock, air, water and organisms. A few metals including copper, manganese and zinc are required by plants in trace amount. It is only when metals are present in bio-avoidable forms at excessive levels that they have the potential of becoming toxic to plants and animal (human inclusive) (WHO, 1972). Copper in its application is used for electricity equipment (60%), construction such as roofing and plumbing (20%) industrial machinery such as Heat Exchanger (15% and alloys (5%). Copper is also available in our environment because it occurs naturally and spares through natural and phenomena.

The world's copper production is still rising suggesting that more copper end up in the environment. Rivers have depositing sludge on their banks that is contaminated with copper due to the disposal of copper-containing waste (Madejon *et al*., 2002). Copper enters the air mainly through release during the combustion of fossil fuel. Copper in air

will remain there for an eminent period of time before it settles, due to rain and eventually end up mainly in soil. Copper can be released into the environment by natural sources such as windblown dust, decaying vegetation, forest fire and sea sprays, human activities such as mining, metal production, wood production and phosphate fertilizer production. Copper is often found near mines, industrial setting, land fill and waste disposal sites (Adeniyi, 1996). Copper compound settle and get abandoned to either water sediment or soil particles (Madejon *et al*., 2002).

Copper can be found in many kinds of food, in drinking water and in air, hence copper is absorbed in eminent quantities each day by eating, drinking and breathing. The absorption of copper is necessary because it is a trace element that is essential for health, but when it gets to an excessive level; it has the potential of being toxic to man and cause eminent health problem (Fergusson *et al*., 1990). Copper concentration in air is usually quite low, so that exposure to copper through breathing is negligible but people that live near smelter that processes copper ore into metal and waste disposal site are exposed to high level of copper (WHO, 1972). Long term exposure to copper can cause irritation of the nose, mouth and eyes, headache, stomach ache, dizziness, vomiting and diarrhoea (WHO, 1972). Long term exposure to high concentration of a copper has been indicted in the decline in intelligence in young adolescent (WHO, 1972). Chronic copper poisoning result in Wilson diseases which is characterized by hepatic cirrhosis, brain damage, demyelization, renal disease and copper deposition in the cornea (WHO, 1972). Potential

exposure has been investigated in connection with cancer, asthma, respiratory diseases and birth defects like Down syndrome (WHO, 1972).

When copper ends up in soil, it strongly attaches to organic matter and minerals as a result; it does not travel far after release. Copper does not break down in the environment and because of this, it accumulates in plants and animals. On copper-rich soil, only a limited number of plants have the chance of survival, this account for less plant diversity near copper-disposing factories. Due to the effects upon plants, copper can seriously influence the proceeds of farmlands. Copper interrupts the activities in soil as it negatively influences the activities of micro-organisms and earthworms leading to reduced decomposition of organic matter. When the farmland soils are polluted with copper, animals absorb concentrations that are damaging to their health. For example, sheep suffers a great deal from copper poisoning. It has a way of contaminating the flora and fauna that are in contact with contaminated land leading to possible bio accumulation of toxic material in flora and fauna, and vegetation damage (Alloway, 1995).

Heavy metal phytotoxicity is known to be the main factor limiting plant growth, and thus crop cultivation in acid soils (Foy, 1988). Chromium is known as a strong toxic element. Chromium ions are tightly bound to humus and clay particles and are more or less insoluble in the soil. Its availability in plants is therefore generally low but mobility and availability are relatively decreased with the increasing pH. Since seed germination is the first physiological process affected by chromium (Cr), the ability of seed to germinate in a medium containing Cr would be indicative of its level of tolerance to this metal (Peralta

et al., 2001). When the concentration of the chromium in the soil reaches a threshold level, the ability of the plant to hold the Cr breaks down and thus the metal exerts its toxic effect in any system of cell metabolism and kills the seed if it is present in large amount at that condition, Sensitive species serve as an indicators and tolerant species, which collect large amount of metals in their cell wall without any damages detected are known as accumulators (Bradshaw *et al.*, 1965).

Cr (VI) is considered the most toxic form of Cr, which usually occurs associated with oxygen as chromate (CrO_4) or dichromate (Cr_2O) oxy anions that have a long residence time and high solubility in the water (Klieman and Cogliatts, 1998). Cr interferes with several metabolic processes causing toxicity to the plants as exhibited by reduced root growth and phytomass chlorosis, photosynthetic impairing, stunting and finally plant death; Gardea –Torresday *et al.*,(2004) observed that 0.5 ppm of chromium as chromium sulphate stimulate growth in hydrophonic experiment with maize .They found that the growth was inhibited by 5ppm and strongly inhibited by 50 ppm . El-Bassam (1978) reported that low Cr^{3+} concentration promote plant growth and also stimulate chlorophyll synthesis and photosynthetic activity.

There has been increased concern about lead in the environment which comes mainly from its use as anti-knock additive in petrol (Garg and Agarwall, 2011). Lead is toxic at low concentration and has no known function in biochemical processes (Haggins and Burns, 1975). It is equally added such that increased use of metal based fertilizer in the agricultural revolution of government could result in a continued rise in the concentration of metal pollutants (Adefemi *et al.*, 2008).Zinc is an essential trace element for the

normal healthy growth and reproduction in some plants and enzymatic system. Presence of zinc in high concentration has been found to decrease respiratory rate and increased membrane damage in sunflower plants and affected the accumulation of other nutrients in different plants (Ismail and Azooz, 2005). Lead inhibits some metallic activities in plant such as the biosynthesis of nitrogen compounds, carbohydrate metabolism and water absorption (Sharma and Dubey, 2005; John *et al*., 2006; Hamid *et al*., 2010). Plant exposed to lead showed a considerable decrease in their dry weight and a decline in the total chlorophyll and photosynthetic efficiency (Kosobrukhiov *et al*., 2004). The plant processes are adversely affected by increasing lead ion level in the soil and even at very low concentration (Patra *et al*., 2001). Plants on land tend to absorb lead from the soil and retain most of this in their roots (U.N.E.P, 1991). There are some evidence that plant foliage may also take up lead (and it is possible that this lead is moved to other part of the plant). The uptake of lead by the roots of the plant may be reduced by the application of calcium and phosphorus to the soil (W.H.O 1991). Some species of plant have the capacity to accumulate high concentration of lead (I.L.O.1991). Most heavy metal-tolerant species have the capability of preventing heavy metal accumulation in shoot and therefore are called excluder while others can take up heavy metals, translocate them into the shoot and accumulate them in non-metabolic active tissues and organ in less harmful form and these plant are called hyper-accumulators (Kupper *et al*., 2007).

Chromium is another metal that is of interest in this project work. It is the 21st most abundant in the earth's crust (Krauskoff, 1979). It occurs in bound form that constitutes.

0.1-0.3mg/kg of the earth crust. Cr has several oxidation states ranging from Cr (-II) to Cr (+VI). The intermediate state of +IV and +V metastable and rarely encountered (Zayed and Terry, 2003).

Cadmium adversely affects several important enzymes. It can also cause painful osteomalacia (bone disease), destruction of red blood cell and kidney damage. Cadmium is chemically very similar to zinc and are found in the +2 oxidation state. It is believed that much of the physiological action of cadmium arises from its chemical similarly to zinc. Specifically, Cd may replace Zn in some enzymes thereby altering the stereochemistry of the enzyme and impairing its catalytic activity, disease symptoms ultimately result. Arsenic forms a number of toxic compounds. The toxic As_2O_3 is absorbed through the lungs and intestine. Biochemically, arsenic acts to coagulate proteins, and inhibits the production of adenosine triphosphate (ATP) in essential metabolic processes.

Lead is the major pollutant in both aquatic and terrestrial habitat. Beside natural weathering processes, the main sources of Pb pollution are exhaust fumes from automobiles, industries, mining and smelting of Pb ores, fertilizers, pesticides and additives of gasoline(Eick *et al.,* 1999). Sewage sludge containing large quantities of Pb and other metals is regularly discharged into the fields, garden soil due to increase in the trend of urbanization (Paivoke, 2002).

Cadmium (Cd) is a highly toxic heavy metal in the environment (Davis, 1984; Guo, 1994). Cd is a non-essential nutrient for plants, and excessive Cd has not only significant

adverse effects (Shamsi et al., 2008), but also endangers human health via food chain (Naidu and Harter, 1998). The alleviation or inhibition of Cd damage therefore caused extensive attention of the whole society (Wang *et al*., 2008; Uraguchi *et al*., 2009). Heavy metal has an adverse impact on growth and development of the plants, showing some physiological and biochemical characteristics of damages. To a certain extent, plant growth and physiological characteristics can reflect the adverse impact of heavy metal externally or internally (Zhang and Shu, 2006).Cadmium pollution is regarded as one of the most harmful environmental issues that mainly resulted from mining, use of phosphatic fertilizers, sewage sludge and untreated wastewater (Kováčik *et al*., 2006). Elevated concentrations of Cd in agricultural soil shave posed a significant threat to safe crop production and have therefore become a global concern (Mohamed, 2012).Uptake and accumulation of heavy metals at higher concentrations can be cytotoxic in some plant species, causing structural and ultrastructural changes affecting the growth and physiological wellbeing of the plants (Repcák and Krausová, 2009). Cd accumulation causes a breakdown of chloroplasts in bush bean plants (Ismai, 2008) and decreases plant growth in *Brassica napus* (Wan *et al*., 2011).

Several researches demonstrate that great interrelationship exists between the nutrition status of the plants and the degree of accumulation and toxicity of heavy metals such as cadmium (Hall, J.L., 2002).Plant root directly remove nutrients and metals from the soil solution and plant responsibilities are accompanied by a range of leaf symptoms which can be used to aid diagnosis. Copper toxicity often causes foliar interventional chlorosis, the leaf becoming necrotic with increasing exposure (Sharma and Dubey, 2005).

Manganese toxicity systems include chlorosis of older leaves, necrotic spotting and a symptom on young foliage known as “crinkle leaf” (Sharma *et al*., 2005).

Heavy metal decreases growth rate of plant by affecting various part of root metabolism such as water and mineral uptake membrane function, inhibition of cells division, induction of DNA damage and cell death (Tang *et al*., 2009). The toxic effects of metals have been studied at the level of biochemical-physiological process such as photosynthesis (Kupper *et al*., 2002).

Plant species vary significantly in the ability of accumulating metals from contaminated soils, as a balance between the uptake of essential metal ions to maintain growth and development and the ability to protect sensitive cellular activity and structures from excessive levels of essential and non-essential metals are required (Garbisu and Alkorta, 2001). Generally, metals enter the plants primarily via absorption of the available metal ions from the soil solution into the root symplasm, driven by the electrical chemical potential gradient across the plasma membrane of root cells (Blaylock and Huang, 2000). These precipitates are then immobilized in the apoplastic (extracellular)- cellular walls and intercellular spaces-and symplastic (intracellular) compartments, such as vacuoles (Raskin *et al.,* 1997). Unless the metal ions is transported as a non-cationic metal chelate, apoplastic transport is further limited by the high Cation Exchange Capacity (CEC) of cell walls (Raskin *et al.,* 1997). Some metals may be transported to the shoots by the transpiration stream complexed to organic acids, mainly citrate (Senden *et al.,* 1992).

Some naturally occuring plants, termed *metal hyperacumulator plants,* can accumulate in their harvestable tissues abnormally high levels of some metals. According to Reeves and Baker (2000), the term hyperacumulator, describes a plant with a highly abnormal level of metal accumulation, appears to have been first applied by Jaffr`e *et al* (1976), who reported high Ni concentrations in the New Caledonian plant *Sebertia acuminate*. The definition of hyperaccumulation has been extended to elements other than Ni. For example, 1000mg/kg criterion were used for Co, Cu, and Pb accumulation (Brooks *et al.*;1980*;* Reeeves and Brooks, 1983*)*. For Zn, normally present at higher and more widely ranging concentrations, a 10,000 mg/kg threshold was suggested by Baker and Brooks (1989). The present definition of an hyperaccumulator is more extensive and should meet the following requirements: the concentration of the metal in the shoot must be higher than: 0.1% for Zn, Mn, Al, As, Se, Ni, Co, Cr, Cu and Pb; 0.01% for Cd (Baker and Brooks, 1989).

The shoot to root concentrations ratio must be invariably higher than 1 (McGrath and Zhao, 2003), indicating an efficient ability to transport metals from roots to shoots and most likely, the existence of tolerance mechanisms to cope with high concentrations of metals; and the shoot to soil concentration ratio must be higher than 1, indicating higher metal concentrations in the plant than in the soil, which emphasizes the degree of plant metal uptake (McGrath and Zhao, 2003). Plants growing in metalliferous soil can be grouped into three categories according to Baker (1981). a) Excluders, in which metal concentrations in the shoots are maintained at low level up to a critical value across a

wide range of soil concentrations; b) accumulators, in which metals are concentrated in above-ground plant parts from low to high soil concentrations; and c) indicators, in which the internal concentrations reflect external levels. Moreover, the bioavailability of trace elements for plants is dependent on many environmental factors: concentrations of heavy metal in the environment, abiotic factors, exposure time, growth form of the plant, type of absorption mechanisms, affinity of trace elements for the absorption sites and element speciation (Mazeij and Germ, 2009).

The identification of metal hyperaccumulators, plants capable of accumulating extraordinary high metal levels, demonstrate that plants have the genetic potential to clean up contaminated soil (Nadia *et al.,* 2012). Hyperaccumulators are also characterized by a high shoot-to-root metal concentration ratio (i.e. the translocation factor of more than 1), whereas non-hyperaccumulator plants usually have great metal concentrations in the roots than in the shoots. Several authors (McGrath and Zhao, 2003; Sun *et al.*, 2008) included the bioaccumulation factor (BAF) as an element for classification as a hyperaccumulator species. The BAF refers to the plant metal concentration in root and the soil metal concentration ratio. This ratio should be greater than 1 for inclusion into the hyperaccumulator category. Importance of hyperaccumulators has been emphasized on further research in exploring the contaminated sites and finding new hyperaccumulator plants (Nadia *et al.,* 2012). Many plant species have become metal tolerant due to the adaptive responses of plant species to heavy metals, as these species are growing in contaminated sites over a long period (Nadia *et al.*, 2012).

Some heavy metals at low concentrations are essential micronutrient to plants, but in higher doses, they may cause metabolic disorder and growth inhibitions. The toxic effects of metal in different plants may differ significantly (Leon *et al.*, 2002).Researchers have observed that some plant species are endemic to metalloferous soil and tolerate greater than usual amount of heavy metal or other compounds (Opeolu *et al*., 2010). Heavy metal toxicity includes inactivation of bio-molecules by either blocking essential functional growth or by displacing essential metal ions (Goyer, 1997). The toxic effects of heavy metals in different crops may differ significantly (Komarek *et al.*,2008).The phytoxicity of heavy metals due to industrial pollution has serious implication on soil degradation (Zayed and Terry, 2003). This may reduce both the quantity and productivity of plants.

Disposal sites are known for their smelly and unsightly conditions. These conditions are worse in the summer because of extreme temperatures which speed up the rate of bacterial action on biodegradable organic material. Most developing countries properly manage their dumpsites and make environmentally safe landfills. There is therefore considerable public concern over the possible effect of this disposal means. The assessment of dumpsite soil and plants for the concentration levels of hazardous metals is imperative for healthy crop production.

In a study of trace – element content of municipal wastes, wide ranges of B, 3.8 to 103 ppm; Pb, 44 to 352 ppm; Cu, 25 to 215 ppm; Ni, 7 to 21 ppm; and Zn, 400 to 655 ppm were reported. In spite of the foregoing, most abandoned waste dump sites in many towns and villages in Nigeria attract people as fertile ground for cultivating varieties of crops.

The cultivated plants take up the metals either as mobile ions present in the soil solution through the roots (Davies, 1983) or through foliar adsorption (Chapel, 1986). The uptake of the metals by crops results in the bioaccumulation of these elements in plant tissues. This is known to be influenced by the metal species, plant species and plant part (Juste and Mench 1992). Indeed it has been reported that plants grown on soils possessing enhanced maked concentration due to pollution have increased heavy metal ion content (Alloway and Davies, 1971; Grant and Dobbs, 1977).If the consumption of these metals through plant sources is not carefully regulated, it may lead to accumulation in man with attendant health hazards. Yet, man is the target of numerous other chemical influences in the environment.

Various studies have been conducted to evaluate the heavy metal uptake by plants in relation to soil pollution and atmospheric deposition on the surface of soils (Haghiri 1973; Institute for Soil Fertility, 1988; Voutsa*et al.*, 1996). Variable results were reported for example Larsen *et al.* (1992) found elevated concentrations of Cr and As in soils and plants around a wood preservation factory in Denmark. Around a cadmium (Cd) processing factory in Germany, very high Cd levels were found in soils and in the banks of Grumbach brook, which resulted in very high Cd levels in lettuce, onions, and parsley that exceeded the limit values were reported. In contrast, Ward and Savage (1994) observed no high values of trace metals in crops located near a superhighway in London, despite the fact that Lead (Pb) content in the surface soil was significantly increased.

The accumulaton of heavy metals by plants; root, stem, and leaves grown in polluted soil have been reported. Okoronkwo *et al.* (2005a, b) reported the levels of Pb, Ni, and Cd in the root and leaves of cocoyam (*Colocasia esculentum*) and cassava (*Mannihot esculentum* Cranz) harvested from an abandoned waste dump soils in Umuahia, South-Eastern part of Nigeria. The average mean concentration of Pb was 111.75±17.78 and 76.63±19.94 mg/kg, respectively in leaves and roots of cassava. The concentrations of Ni and Cd in both roots and leaves were 24.47±1.88 and 4.10 mg/kg, respectively. For cocoyam, the concentrations of Pb were 83.02±27.84 and 105.37±45.37 mg/kg in the root and leaf respectively, while the root and leaves had similar values of 22.59 and 4.10mg/kg for Ni and Cd, respectively.

Anikwe and Nwobodo (2002) reported high level of heavy metals (Pb, Fe, Cu and Zn)in their study on long term effect of municipal waste disposal on soil properties and productivity of site used for urban agriculture in Abakaliki , South eastern part of Nigeria. Amusan *et al.*(1999) studied plant uptake of heavy metal on a similar site at University of Ife garbage dump and found out that Pb, increased in leaves and roots of waterleaf and okra relative to those grown in non-dump site. These investigators recorded 83.92mg/kg Pb contents in water leaf (leaves) in the dump site soil against 3.99mg/kg from a non-dump site soil. Similar work by Ademoroti(1995)showed that vegetables accumulated considerable amount of heavy metal (Pb ,Cr,Cu,Zn)in roots and leaves. Arsenic (As) has been detected in root of cassava (Okoronkwo Unpublished data). Furthermore, Alloway and Ayres(1997) reported that Cd, although present in quite low

concentration(<10mg/kg) is relatively taken up by food crops especially leaf vegetables and enters the human diets. Nwoko and Egunjobi (2002) studied lead contamination of soils and vegetable in an abandoned battery factory site in Ibadan, Nigeria and reported the high concentration of Pb in the tissues of plants with roots containing higher residual Pb than shoots in most cases.

Jeanne and Sidle(1991) reported the presence of heavy metals in vegetables grown on abandoned Pb- Zn tailings pond. Also, Pb was reported in vegetables grown near busy traffic highways (Ndiokwere, 1984; Ihenyen, 1991).Chiroma *et al*. (2003) studied heavy metal contamination of vegetable and soils irrigated with sewage water in Yola, Nigeria and reported high concentration of the metals (Fe, Zn, Cu, Mg, Mn and Pb) suggesting heavy metal contamination of the soil irrigated with sewage water and their accumulation in different parts of plants cultivated in the soil. They also showed that the metal concentration vary in the different parts of the plants. Moreover, the result indicated that Fe has the ability to accumulate in roots and leaves but Zn accumulates in roots and translocates gradually to the leaves while Mn and Mg showed greater accumulation in unwashed leaves. There was also the ability of high metal concentration on the unwashed plants compared to the washed plants. Similar work by Sonuhmacher (1993) who studied the levels of Cr, Cu, and Zn in washed edible vegetable reported the same range of level present in the crops. Furthermore, studies have revealed that Pb does not readily accumulate in the fruiting part of vegetable and fruit crops (e.g. corn, beans, squash,

tomatoes, strawberries, apples); higher concentrations are most likely to be found in leafy vegetables (e.g. lettuce) and on the surface of root crops (Rose, 2002)..

Vegetables are rich sources of vitamins, minerals, trace elements and fibres, and are with beneficial antioxidant activities. They constitute an important part of the human diet. Heavy metal contamination of the food items is one of the most important aspects of food quality assurance (Wang*et al*., 2006). Heavy metals are known to pose a variety of health risks such as cancer, mutations or miscarriages (Weigert, 1991). They are ranked high among the chief contaminants of leafy vegetables (Mapanda *et al*., 2005). Due to their toxic and mutagenic effects even at very low concentrations, they are given special attention throughout the globe.

The implication associated with heavy metal contamination is of great concern, particularly in agricultural production systems. These metals can pose a significant health risk to humans, particularly in elevated concentrations above the very low body requirements (Gupta and Gupta, 1998). Heavy metals, in general are not biodegradable, have long biological half-lives and have the ability of accumulation in the different body organs leading to serious health side effects (Sathawara *et al*., 2004). Copper (Cu) is an essential element but excessive exposure can cause hepatic and kidney damage, haemolytic anaemia and methanoglobinemia (Chugh *et al*, 1975). High concentration of cadmium exerts detrimental effects on human health and causes severe diseases such as tubular growth, kidney damage, cancer, diarrhoea and incurable vomiting (Abbas *et al*., 2010). If the concentration of lead exceeds the maximum permissible limits in human, it

affects nervous system, bones, liver, pancreas, teeth and gum and also causes blood diseases (Abbas *et al*., 2010). Chromium VI causes skin rashes, stomach upset and ulcers, respiratory problems, weakened immune system, kidney and liver damage, alteration ofgenetic material and lung cancer (Avena, 1979)

The content of lead in the soil varies from 13 to 60 mg/kg (Directive of the Minister of Environment, 2002). The mean content of this element in arable land in Poland is not high (13.8 mg/kg), but the range of concentrations is wide and may be from 0.1 to 1723 mg/kg (Kabata-Pendias. *et al.*,1999).The content of chromium in soils is low (from 7 to 150 mg/kg). It is assumed that the natural content of chromium in the surface layer of soil in Poland (0-20cm) is from 2.0 to 81.0 mg/kg (Kalembkiewicz, 1999;Swietlik *et al.*,2004). The content of zinc in soil varies from 7 to 360 mg/kg. The content of zinc in urbanized areas in the surface layer of soil should not exceed 300 mg/kg (Directive of the Minister of Environment, 2002), and according to the Polish Standard, the content of bioavailable zinc of over 51 mg/kg in heavy mineral soils is considered high (PN-R-04016).

The level of cobalt in the soil varies within a wide range from 0.1 to 100 mg/kg. According to the Catalogue of Environmental Protection, its natural content in the Polish soils varies from 1.0 to 18 mg/kg (Ostrowska *et al.*, 1991) but its content in urbanized areas should not be higher than 20 mg/kg in the surface layer of the soil (Directive of the Minister of Environment, 2002).Heavy metals such as Cd and Pb are non-essential elements for plants. If high concentrations of these metals are accumulated in the plants,

they will adversely affect the absorption and transport of essential elements, disturb the metabolism, and have an impact on growth and reproduction. (Xu and Shi, 2000). The germinating ratio and growth rate of barley declined, for instance when polluted by Cd, and the decline was related to the dosage and duration. The germinating ratio was lower than 45% and the growth of roots were stagnant under 10^{-2} mol/L Cd treatment (Zhang, 1997). The seedlings of bean became brown and died under Cd stress (Mo and Li, 1992). The roots were one of the target organs of Cd pollution, so that the root growth of crops such as wheat (Hong *et al*., 1991) and garlic (*Allium sativum* L.) (Liu *et al*., 2000) were inhibited.

Seedlings represent a more easily damaged stage of plants life cycle. In crops, such as rice and cotton (Qin *et al*., 2000), and vegetables such as spinach (*Spinacia oleracea* Linn.) (Song *et al*., 1996), seedlings were easily injured and inhibited by the heavy metal pollution in a hydroponical exposure (Yang *et al*., 2001). The growth of vegetables such as cabbage, carrots, broccoli and cucumbers were inhibited under exposure to 10 mg/l Cd solution (Liu *et al*., 1995). Yang *et al*. (1999a) studied the effects of Cr^{6+} on *Hydrochair dubia* (B.l) Backer and showed that Cr prevented it from absorbing water. The degree of damage was positively relative to the cultural concentration of Cr^{6+} (16-32 mg/kg), the edge of the leaves began to dry and the root tips rotted in a short period of time.

The effects of heavy metals on plants are different at different growth stages of plants. In the early stage, Cd inhibits the photosynthesis and growth of rice, then inhibits the reproductive organs' differentiation, and finally distort the nutrients transport and

mobilization (Wang, 1996), but a low concentration of Hg (10^{-5} mol/l) stimulated the growth of wheat seedlings. The reason for this may be that low concentrations of Hg increased the activities of amylase, proteinase and lipase, sped up the decomposition of endosperm and the respiration rate, so that the germination was more rapid (Ma and Hong, 1998).Root vitality is reduced under heavy stress. Shu *et al*. (1997) measured the root vitality of *Stylosanthes guinensis* in mine tailings, it was reduced by heavy metals (Pb, Zn, Cu and Cd), and the absorption of inorganic nutrients was prevented and led to evident chlorosis, which significantly affected the growth. Heavy metals affect the cell division of plants, and the effects are different and depend on the concentration. Mo and Li (1992) studied the effects of Cd on the cell division of root tips in beans. Duan and Wang (1995) treated the beans by using Cd, Pb and Zn and reported that the cell division was extended under a low concentration of 0.01, 1.0 and 10 ppm of Cd, Pb and Zn, respectively, while cell division was shortened but the cell cycle was extended by increasing the dose. Zhang (1997) investigated the effects of Cd, Hg and Pb on the cell division of barley (*Hordeum vulgare*) and showed the trend of cell cycle extension under 0.01 mol/l concentration treatment. Cd, Hg and Pb affected the nucleic acid and damaged the structure of the nucleolus after 24hrs of treatment. With a 0.005- 0.0005mol/l dosage, the DNase and RNase activities were inhibited (Duan and Wang, 1992), thus resulting in the interruptive synthesis of DNA (Yang and He, 1995a) which affected cell division.

Treated with heavy metals, the cell division exponent was changed, and relates to the elements and the treatment manner. Treated by low concentration of heavy metals (Pb

(1.0 ppm) and Cd (0.01 ppm), the cell division exponent raised from 16% to 20%, while increasing the concentrations of heavy metals, the cell division exponent declined and revealed a negative relationship to the dosage of heavy metals (Duan and Wang, 1995). But, it did not show such results following different concentrations of Hg treatment. Hg inhibited the cell division of beans, garlic and onions (Mo and Li, 1992).

The low and high dosage of heavy metals treatments revealed opposite effects on the same physiological activity of plants, which means a stimulation reaction of plants to low heavy metal stress. In the procedure, physiological and biochemical activities of plants are sped up, producing high amounts of metabolized products such as glutathione (GHS), oxalic acid, histidine, citrate and metal-binding proteins to combine heavy metals and to detoxify (Zhang *et al*., 1999). The high dosage of heavy metals, on the other hand, results in an enhanced metabolism and increases the entrance of heavy metals into cells. If the metabolism is inhibited, toxicity to the plants is revealed (Zhao and Bi, 1999).

Peng and Wang (1991) studied the effects of Cd on the cell ultrastructure of maize and showed that the grana cascade of chloroplast and mitochondria decreased and/or disappeared under low concentrations of Cd stress. The chloroplast cascade became more extensive and the membranes began to decompose, the mitochondria also became tumorous and decomposed, under high concentrations of Cd stress (Peng and Wang 1991). The damage to the chloroplasts was related to the attachment of Cd to the thylakoid and combined with the protein in the membrane to destroy the enzymatic system of the chloroplasts and to block the synthesis of chlorophyll. The thylakoids of

chloroplast and lumen of mitochondria of *Hydrocharis dubia L.* swelled in the early stages when the leaves suffered poisoning due to Hg (Hao *et al*., 2001). Also, the polypeptide compositions of the thylakoid membrane of *Braseniaschreberi*were degraded under the stress of Hg and Cd (Chen *et al*., 1999). The changes in the mitochondria resulted from the penetration of K^+ and H_2O from the lumen to the outside and the disturbance of the Cd on the activities of ATP. Yang (1991) also reported the effects of heavy metals on the structure and function of photosynthetic membranes of higher plants and showed that the sub-microstructure of chloroplast were changed. The grana also decomposed and some plasmids were formed. In intact tobacco (*Nicotiana tabacum*), the photosynthetic membranes were damaged by Cd treatment, which might be the main reason for the decrease in photosynthetic intensity (Jiang, 1995).

Palisade and spongy mesophyll, and the disintegration of cells were destroyed under Cd and Hg stress (Li *et al*., 1998; Li and Shi, 1999; Li et al. 1999a). Under the stress of Hg, it was the mature leaves of *Brasenia schreberi L.*, it was observed that palisade and spongy mesophyll were destroyed and that there was a disintegration of cells when mixtures flew into cell crevices; the basic microstructure of the petiole did not change, but the starch grains almost disappeared (Li *et al*.,1999a). In young leaves, although the microstructure did not change as well, the number of starch grains decreased very much, especially starch grains in the cell layer which was under the upper epidermis (Li *et al*., 1998). Li *et al*., (1999a) treated floating leaves of *Trapa bicornis* Osbeck with Cd at a concentration of 50 and 100 umol/l, the cells were seen to be out of shape and broken; the tissues came

loose and deformed, including the destruction of the palisade and spongy mesophyll. In the cells of the leaves, nuclear substance disappeared, but the nuclear membrane remained intact. The number of chloroplast grana decreased, layers of grana disintegrated and the chloroplast envelope became distrupted. The utralstructure of nuclear and chloroplast in stomata of *T. bicornis* treated by Cd and Hg (10-50uμmol/l Cd or Hg solution) was also studied by Li and Shi (1999) and observed the destruction was seen to have increased as the concentration of heavy metal solution rose.

Under Cd stress, electron dense globules were usually deposited in the vacuoles in the root tube cells of garlic *(A. sativum*) (Liu et al., 2000). These globules, whose electron density was greater outside than inside were big or small and distributed near the vacuoles in the cytoplasm. Nucleoplasm in most of the nuclei was highly densed, and other effects like the formation of plasmolysis, disintegration of cell organelles were reviewed as well. The result from x-ray micro-analysis showed that there were no Cd ions in these globules and indicated that the epidermal cells of the root tip treated with higher concentration of Cd (10^{-2}mol/l) appeared to be more hardened; the cell was obviously increased in thickness and many mucilage exudates were deposited in the cell walls. Pb, Cd and Zn influenced the conformation of wheat DNA and change DNA UV absorption peak value. Pb has the greatest effect on the DNA conformation, the hypochromicity and the separation of DNA. The effects of Cd is relatively small and may result in a slight hypochromicity. Zn of low concentration (10mg/l) leads to hypochromicity as well (Meng *et al*., 1998a)

The hydroponical experiment of oat showed that the absorption capacity of K and Mg declined in suspended cultivated cells, and the absorption of Ca, Fe and Zn rose by Cd pollution. However, absorption of Zn declined in higher concentration of Cd solution (Xu and Yang, 1995). Wang (1990) reported that Cd significantly inhibited maize seedlings from absorbing N, P and Zn and enhanced the absorption of Ca. Cd also affected the absorption of Mn and Zn by the roots of *B. chinenses* seedlings. (Qin *et al*., 1994), inhibited the absorption of Fe, Mn, Cu, Zn, Ca and Mg by ryegrass (*Lolium perenne*), maize (*Zea mays*), shamrock (*Trifolium repens*) and cabbage (*B. oleracea var. capitata*) and increased the absorption of P (Yang *et al*., 1998). The results showed that Cd inhibited the absorption of N, K, Mg, Mn by plants. The effects on absorptions of Ca, Zn, Fe are more complicated and are related to plant species and environmental stress, pH and elements.

Yang *et al*. (2000) reported that organic and amino acids (such as citric acid, succinic acid, oxalic acid, tartaric acid, aspartic acid and glutamic acid) excreted by the roots of plants formed soluble complexes with heavy metals and increased the mobility of such heavy metals(Cd,Cu, Pb and Zn) in soil. Chelators, EDTA and DTPA when added to the nutrient solutions significantly reduced the uptake rates of Zn, Cu, and Mn by *Thlaspi caerulescens.* J and C Presl (Shen *et al*., 1998). The growth of *B. chinenses* seedlings was inhibited by 200mg/l $CdCl_2$. When 10mg/l LaGly was used to spray the plant one time, the damage effect of Cd was reduced (Zhou *et al*., 1997).

pH affects the behaviour of heavy metals in the soil. The concentration of heavy metals in the soil can be reduced by acid rain (Meng and Li, 1998) and increase the content of heavy metals in leachate. The effects of leachates on plants increased as the duration and initial acidity of leaching (Lan *et al*., 1996). Studies on the bio availability of Cd in plough horizons showed that the uptake of Cd by ryegrass increased with a decline in pH and declined with an increase of pH, and the plant available sources of Cd mainly came from the soil exchangeable Cd as well as Cd weakly bound to organic substances (Zhu and Shao, 1997).

CHAPTER 3

3.0 RESEARCH METHODOLOGY

3.1 Study area - The study was carried out in Kwara State. Kwara state has tropical climate, with an average annual temperature of 26^0C and an average rainfall of 1217mm annually. The vegetation type is derived savannah with riparian forest along the river banks. Three urban locations were selected which were Oko-Olowo in Ilorin, Offa and Omu-Aran while three rural areas were selected Odo-Ore, Ipee and Aran-Orin. Major dumpsites were selected as farming in each of these locations. Oko-Olowo dumpsite has been in existence for about 40 years, Offa dumpsite has been in existence for about 18 – 20 years while Omu Aran dumpsite has been in existence for more than 20years. Odo-Ore dumpsite has been in existence for about 30-40 years with their major occupation as farming in Yam, maize and guinea corn, Ipee dumpsite has been in existence for more than 20 years with their major occupation as farming in Maize, Cassava and Yam while Aran –Orin dumpsite has been in existence for more than 50 years with their major occupation as farming. The samples were collected in September, 2015. The coordinates of each dumpsite were taken with the aid of hand-held Global Positioning System device.

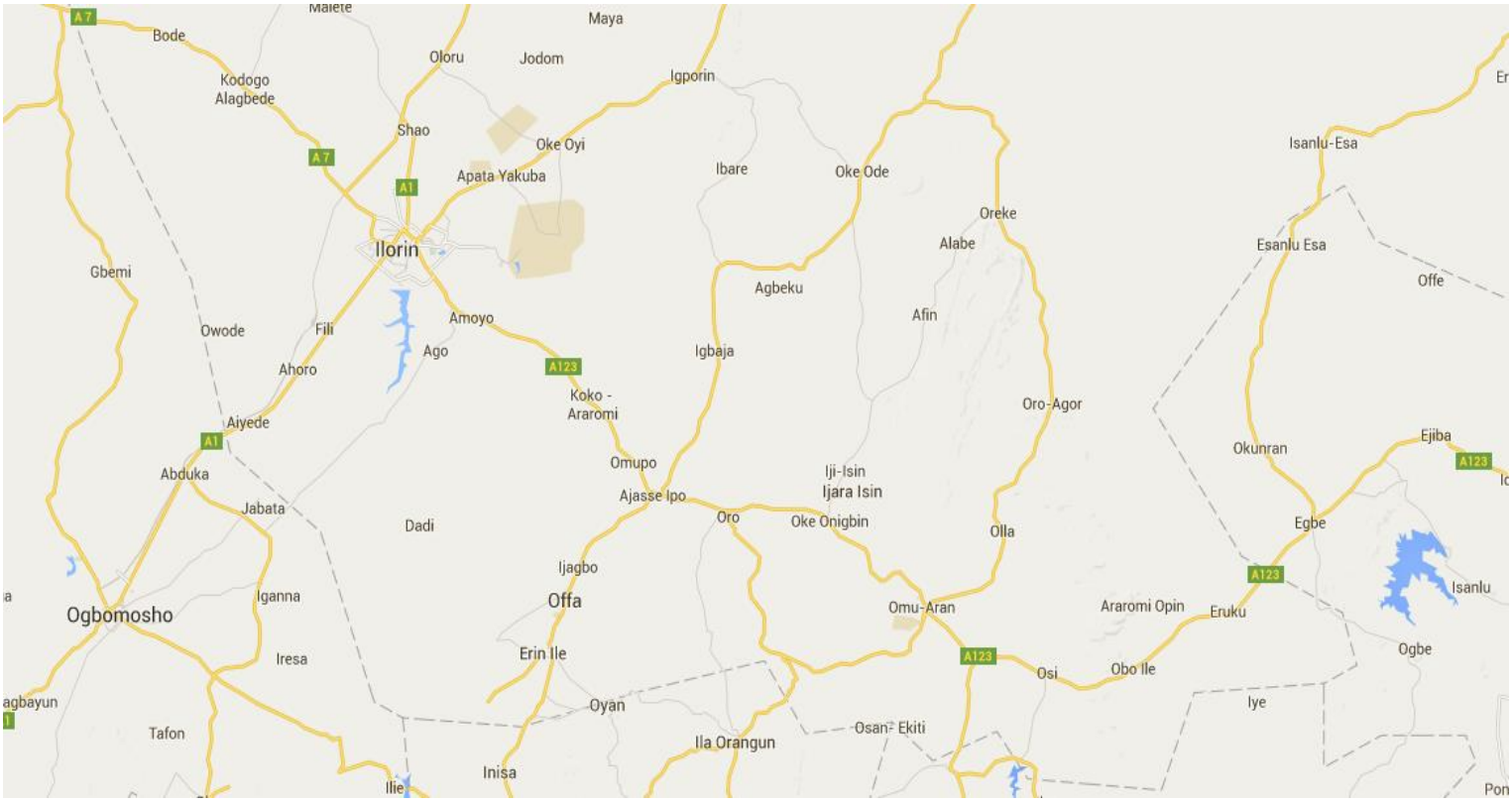


Figure 1. Map of Kwara State showing the dumpsite locations

3.2 Method of sampling used – Simple Random Sampling (SRS) method was used to collect the samples

The sample collection spanned for a period of two years between September 2015 – December, 2017. The planting was done between September, 2017 and January, 2018.

3.3 Sorting of Waste

Waste sorting is the process by which waste is separated into different elements (*Wikipedia.org 2014*). Waste sorting was done manually at the dumpsites. The waste were sorted into organic and inorganic waste.

3.4 Collection of Soil Samples - Soil samples were collected from the center of each of the dumpsite and at every 10m interval up to 40m. The soil samples were collected at 0-15cm depth with clean stainless soil auger. At each of the dumpsites, five representative soil cores were collected and placed in separate polyethylene bags. All soil samples collected were properly labelled and kept in polyethylene bags. Soil samples were collected at least 1km from the dumpsites which was taken as an uncontaminated area where there was no dumpsites or any form of human activities that could generate waste to serve as the Control and the samples were placed in polyethylene bags and labelled appropriately..

3.5 Collection of Plant Samples - Plant samples were collected from the center of each dumpsite where the plant samples were taken from and at every 10m interval up to 40m. The native plants were gently uprooted at each point of collection, placed in polyethylene bag and properly labelled. Plant samples were collected at least 1km from the dumpsites which was taken as an uncontaminated area where there was no dumpsites or any form of human activities that could generate waste to serve as the Control and the samples were

placed in polyethylene bags and labelled appropriately. The choice of plant species collected was based on the presence of the plants at the point of collection

3.6 Identification of Plants – Plants taken from the dumpsites and the Control sites were taken to the Hebarium of the Department of Plant Biology, University of Ilorin, Ilorin for proper identification.

3.7. EXPERIMENTAL PROCEDURE

3.7.1 Pre-treatment of soil and plant samples

The soil samples collected were air dried for seven days and gently ground using laboratory porcelain mortar and pestle and then passed through a 1mm sieve and kept in drug polyethylene of 7cm×10cm size, labelled and sealed for further analysis (Agyarko, 2010). The plant samples were oven dried to constant weight after which they were kept in drug polyethylene of 7cm×10cm size, labelled and sealed for further analysis (Agyarko, 2010).

3.7.2 ANALYSES OF SOIL AND PLANT SAMPLES

3.7.2.1 Digestion of soil and plant samples

Analyses of the elemental contents of the soils and plants were done with the method of Jiang *et al.* (2011). The air dried soil samples from each of the treatment was crushed and ground with a mortar and pestle. Ground soil (0.2g) was carefully weighed into a Teflon beaker and a mixture of 1ml trioxonitrate V acid (HNO_3), 3ml perchloric acid ($HClO_4$) and 1ml hydrofluoric acid (HF) were added to each sample. The content was heated on a hot plate in a fume cupboard till colourless solution was formed. After cooling, the residue was transferred into 25ml volumetric flask and made up to the mark with deionized distilled water.

Similarly, the plant samples i.e. roots, stem and leaves of each plant collection was crushed and ground separately with the aid of a mortar and pestle. Each ground plant sample (0.2g) was carefully weighed into a Teflon beaker and a mixture of 1ml 70% perchloric acid ($HClO_4$) (Sigma-Aldrich Corp, Germany), 5ml trioxonitrate V acid (HNO_3) and 0.5ml sulphuric acid (H_2SO_4) were added to each sample. The content was heated on a hot plate in a fume cupboard till there was an appearance of a clear solution. It was then set aside to cool. Each residue was transferred into 25ml volumetric flask and made to the volume, up to the mark with deionized distilled water.

3.7.2.2 Determination of heavy metal using Atomic Absorption Spectrophotometric method.

Each of the sample was acidified with 1ml concentrated HNO_3 per 100ml sample and autoclaved at 121^0C for 1h to solubilize the particulate matter content. Spectrophotometer was installed on a level and stable platform. A burner was placed under a vent and the correct hollow cathode lamp was chosen. The monochromator was set at the correct wavelength for each of the metals to be detected. The flame was lighted while the flow of fuel and oxidant (Air-acetylene) was regulated. The number was adjusted for maximum absorption.

The stock metal solutions was diluted as required to produce the 5 standard solutions (0ppm, 25ppm, 75ppm and 100ppm). The standard solution was run for the adaptations of the AAS machine to the sample solution. The blank was also run to overcome instrumental drift. After the samples have been run, the concentration of each sample from the machine was printed. The digested samples were then analysed for some selected heavy metals (Pb, Cd, Cr, Ni, Cu, and Fe) contents by using Atomic Absorption Spectrophotometry (AAS) (Perkin Elmer Model 306 and

Bulk Scientific 210 VGP) at the Central Research Laboratory, Obafemi Awolowo University and University of Ibadan, Nigeria.

3.8. Production of Biochar

3.8.1 Biomass Feedstock Preparation

Maize cobs were obtained from maize farmers and maize sellers in Igboho, Oyo state. The maize cobs were sorted and dried to reduce the moisture content of the feedstock to ensure effective carbonization. The dried cobs were shredded to small sizes to provide more surface area for the carbonization.

3.8.2. Carbonization

The maize cobs were carbonized using the conventional drum method (Ugwu *et al*., 2011). The metallic klin is a simple cylindrical designed to provide a means of creating low oxygen environment, it was fabricated using a drum of about 90cm in height and 60 cm in diameter with an opening at the top for loading the maize cobs feedstock. The biomass (maize cobs) was fed to the drum at a manageable batch of 10kg. A fire port was provided at the bottom of the metallic drum and was lit through the wicks. At the start of the carbonization process, the lid was left open for at least 10minutes for the volatile gases to escape. The lid was then closed thereafter to prevent air from entering. The biomass materials was left to carbonize for 45-60minutes with an average temperature of about 450^0C. The fully carbonized materials was collected for further processing and use.



Figure 2: Locally designed pyrolysis kiln used for the production of biochar.

3.8.3. Crushing and sieving

The carbonized maize cobs were ground to fine particles using mortar and pestle, and sieved using a 200micron sieve. The sieved pulverized Biochar was weighed and kept in a poly propylene bag for further analysis and use.

3.8.4 Characterization

The Biochar produced was sent to Sir CV Raman-KS Krishnan International Research Center, Kalasalingam University, Krishnankoil, Tamilnadu India for characterization (SEM with EDX) capability was used to investigate the localized carbon content on the biochars produced, FT-IR analysis was done to know the Surface functional groups on the biochar produced at the Central Research Laboratory of BOWEN University, Iwo, Osun State. The test specimens were prepared by mixing the biochar with KBr at a fixed ratio for fabrication of a translucent disc. The spectrum for FT-IR was in the range of 793cm-1 to 2363 cm-1 with a resolution factor of 4cm-^{1}.

3.9 Field Experiment

3.9.1.

The experiment was designed to test whether the use of biochar as a soil amendment can reduce the heavy metal concentration of soil from dumpsite while at the same time serving as inorganic fertilizer. The effects of Biochar; dumpsite soil, Dumpsite soil with 25% Biochar, Control soil (That is, soil from unpolluted site) and Control soil with 25% Biochar. The seeds of *Abelmoschus esculentum* (L.) Moench, *Amaranthus esculentus* L., *Solanum lycopersicon* L. and *Corchorus olitorious* L. were collected from National Centre for Genetics Resources and Biotechnology, Ibadan, Oyo State while the seeds of *Tithonia diversifolia* (Hemsl.) A. Gray was

picked from nearby farms. Physiological parameters was taken fortnightly until the termination of the experiment.

3.9.2 Soil microcosm experiment

Polyethylene bag were used (height: 0.4m; diameter: 0.15m with perforated bottom: 0.001m) (Anna and Joanna, 2010). Each bag was filled with 3kg of soil samples from the dump sites (Oko-Olowo , Ilorin, Kwara state) and 1kg of biochar for Biochar with dumpsite soil treatment, 4kg of dumpsite soil for Dumpsite soil treatment, 10% biochar with 3.6kg of the Control soil to make Biochar with Control soil and 4kg of Control soil which has been homogeneously mixed. The Control experimental soil was collected around Ladoke Akintola University, Ogbomoso, Oyo State farm which was an uncontaminated area where there was no dumpsites or any form of human activities that could generate waste was put into 15 pots which served as the Controls. The soil was moistened with water from well inside the pots before the planting of seeds of the crops. The treatment were replicated thrice for each of the treatments.

3.9.3 Acquisition of seeds

The seeds of *Abelmoschus esculentum,Amaranthus esculentus, Solanum lycopersicon, Corchorus olitorious*, with the following reference number; NGB 01307, NGB 01662, LO 0169 and NGB 01660, respectively, were collected from National Centre for Genetics Resources and Biotechnology, Ibadan, Oyo State while the seeds of *Tithonia diversifolia* was picked from nearby bush. The seeds were not treated with any chemical before purchase and planting.

3.9.4 Percentage Germination

Each treatment was replicated thrice. The average number of seeds that germinated in three replicates was determined and the percentage germination was calculated as follows:

$$\text{Percentage seed germination} = \frac{\text{Number of seeds that germinated}}{\text{Total number of seeds planted}} \times 100$$

The days to germination for the seeds of each of the crops planted were recorded.

3.9.5 Watering

The moisture content was routinely monitored by watering with 700ml of well water thrice a week.

3.10 ANALYTICAL WORK

3.10.1 Soil moisture content

The soil moisture content was determined by the method described by Schneekloth *et al*,(2002), which involves oven drying the soil to constant weight at 105^0c. Percentage (%) soil moisture was calculated thus:

$$\%\text{soil moisture} = \frac{\text{Initial weight of soil} - \text{Oven dried weight of soil}}{\text{Initial weight of soil}} \times 100$$

3.10.2 pH determination

pH of the soil was determined by using a pH meter on 1:2:5 (w/v) soil/ water mixture (Olabisi *et al*., 2009)

3.10.3 Organic Matter Content

The Organic Matter Content of the soil from the dumpsites was determined by the wet oxidation method (Walkley-Black, 1934).

3.10.4 Measurement of Growth Parameters

The observations noticed from the first day of germination to the day of the termination of the experiment were recorded. The following parameters were taken fortnightly during the period of experiment. This included number of leaves, leaf length, leaf breadth, plant height, petiole's length. Metre rule was used for the measurement and the readings generated was recorded appropriately.

3.10.4.1 Plant height

The measurement was taken fortnightly. The distance between the soil surface and the top of the youngest leaf was taken as the plant height. Metre rule was used for the measurement in centimetre (cm). This was carried out to know the rate of growth of the Treatment and the Control.

3.10.4.2 Number of leaves

This count was done fortnightly, comparing the treatments with the Control. This was carried out to know the rate of increase in the number of leaves and was done by physical counting of the leaves attached to the stem.

3.10.4.3 Leaf length

The measurement was taken fortnightly. Metre rule was used for the measurement in centimetre (cm). This was carried out to know the length of the leaves.

3.10.4.4 Leaf breadth

The measurement was taken fortnightly. Metre rule was used for the measurement in centimetre (cm). This was carried out to know the breadth of the leaves.

3.10.4.5 Leaf Area

The leaf area was calculated by multiplying the length (L) of the leaf by its breadth (B) multiplied by a factor 0.75, which make up for the irregularity in the shape of the leaf. The length and breadth was measured with the use of metre rule.

Leaf area= LxBx0.75 (Moll and Kamprath, 1977).

3.10.4.6 Petiole length

The measurements was taken fortnightly. Metre rule was used for the measurement in centimetre (cm). This was carried out to know the length of the petioles of the plants.

3.11: Models

3.11.1 Geo-accumulation Index (GI)

The GI represents a quantitative measurement of metal pollution in an environment (Agyarko *et al*., 2010; Oyekunle *et al.*,2011).

$Igeo = \log_2 [Cn/ 1.5xBn]$……..Eqn I

Cn is the concentration of heavy metals in the refuse dumpsite soil

Bn is the concentration of heavy metals in the unpolluted sites.

1.5 is the background matrix correction factor

Igeo < 0 means the site is unpolluted

Igeo < 1 means the site is unpolluted to moderately polluted (UP-MP)

Igeo 1< 2 means the site is moderately polluted (MP)

Igeo 2< 3 means the site is moderately polluted to strongly polluted (MP-SP)

Igeo 3< 4 means the site is strongly polluted (SP)

Igeo 4< 5 means the site is strongly to very strongly polluted (SP- VSP)

Igeo >5 means the site is very strongly polluted (VSP)

The background value of 20, 3800, 200, and 9 mg/kg was used as the value for the unpolluted soil for Zn, Fe, Cd and Pb respectively (Oyekunle *et al.*, 2011).

3.11.2 Biological Concentration Factor (BCF) and Translocation Factor (TF)

3.11.2.1 Biological Concentration Factor (BCF)

Biological Concentration Factor (BCF) was calculated as metal concentration ratio of plant roots to soil given in equation I (Ginicchio and Baker, 2004). When BCF is greater than 1, it means the plant is an accumulator, when BCF is less than 1, it means the plants is an excluder.

BCF =[Metals] root ---------- Eqn. II

[Metals] soil

Interpretations: BCF < 1- Excluders

BCF > 1- Accumulators

3.11.2.2 Translocation Factor (TF)

Translocation Factor (TF) is described as ratio of heavy metals in plant shoot to that in plant root given in equation III (Li *et al.*, 2007).

$$TF = \frac{[\text{Metals}]\ \text{shoot}}{[\text{Metals}]\ \text{root}} \quad \text{Eqn. III}$$

TF > 1- High Accumulator

TF< 0.5- Low Accumulator

TF > 0.5 – Moderate Accumulator

3.11.2.3 Biological Accumulation Coefficient (BAC)

Biological Accumulation Coefficient (BAC) was calculated as ratio of heavy metal in shoots to that in the soil given equation IV (Li *et al.*, 2007).

$$BAC = \frac{[\text{Metals}]\ \text{shoot}}{[\text{Metals}]\ \text{soil}} \quad \text{Eqn. IV}$$

BAC < 1- Excluder

BAC > 1- Accumulator

3.12 Hazard quotient

The screening level risk associated with consumption of contaminated food was assessed using hazard quotient (US Environmental Protection Agency (US EPA, 2007). Hazard quotient for adults associated with the intake of metals along with vegetables from experimental sites was assessed using the following formula:

$$HQ = (D) \times (Cmetal) \qquad \text{……Eqn VI}$$

$$(R_fD) \times BO$$

Where the D = daily intake of food (kg/day), C_{metal} = concentration of metal (mg/kg), R_fD = reference oral dose of metal (mg/kg of body weight/day) and BO = Body weight (kg), the average adult body weight is considered to be 64.41kg (Mbada *et al.,* 2009). Daily intake of vegetables was taken as 0.086kg/person/day for adults, as this is the minimum vegetable requirement for a balanced diet. The HQ is a ratio of determined dose of a pollutant to a reference dose level. If the HQ is less than 1, the risk of non-carcinogenic toxic effects is considered to be of no potential risk, that is the exposed population is unlikely to experience obvious adverse effects, If the HQ is more than 1, the exposed population is likely to experience obvious potential adverse health effects (Ogunkunle *et al.,* 2017). The method of estimating risk using HQ was provided in the U.S. EPA Region III risk-based concentration Table (USEPA, 2007). This risk estimation method has been used by researchers (Chien *et al*., 2002; Wang *et al*., 2005) and proved to be valid and useful.

3.13 Standard Reference Material (SRM)

Standard Reference Material (SRM) was used for precision, quality assurance and control (QA/QC) for selected measurements. The soil and plant samples were gotten from International Atomic Energy Agency, IAEA-SL-1 Lake Sediment for soil samples and Cabbage IAEA-359 for the plant samples. Average values of three replicates were taken for each determination

3.14 Recovery percentage

This the ratio of the online value of metals for IAEA to the analysed value of metals for IAEA analysed.

$$\% \text{ recovery of the machine} = \frac{\text{online value of metals for IAEA}}{\text{Analysed value of metals for IAEA}} \times 100$$

3.15 Data analysis

The data generated in this study were statistically analysed with the use of SPSS version 20. The means of the treatment were compared statistically with Analysis of Variance (ANOVA) and the means separated with Duncan Multiple Range Test (DMRT) at 5% level of significance in case of any significant differences. Pearson Moment Correlation Coefficient was also used to know if there was any correlation between the pollution in the plants to those found in the soil.

CHAPTER 4

RESULTS

The common waste items in these dumpsites were nylons, broken bottles, cans, rags, paper, cartons, human faeces, food remains, maize cobs, cococnut husk, stover, growing plants (maize and potato farms).

Table 1: Components of the waste encountered on Dumpsites

Dumpsite	GPS coordinates	Organic wastes	Inorganic wastes
Oko-Olowo	$13^0$46’36’’S $4^0$26’32’’E	Animal remains and growing plants (maize farms), Maize cobs.	Polyethylene bag, tins, bottles, clothes (rags), papers,
Omu-Aran	$18^0$32’47’’S$14^0$24’43’’W	Poultry waste, food remains, Maize cobs, household waste	Polyethylene bag, cans, paper
Offa	$7^0$32’54’’S $16^0$21’48’’E	Food remains/waste Maize cobs	Polyethylene bag, plastics, cans. Clothes
Odo-Ore	$12^0$15’32’’S $32^0$12’34’’E	Human faeces, maize cobs and stover	Polyethylene bag, broken bottles, cans, paper,
Aran-Orin	$7^0$14’30’’S $21^0$16’12’’E	Human faeces, yam peels, cassava peels, maize cobs and stover and growing plants (sweet potato farms)	Polyethylene bag, cans, papers,
Ipee-,	$3^0$15’48’’N $13^0$16’12’’W	Food remains, Coconut husk and Maize cobs and Stover.	Polyethylene bag, cans, papers

Assessment of the heavy metal contents of the soil and plants in the dumpsites

Table 2 shows the heavy metal contents of soil samples collected from the study sites at 0m. The heavy metals were present in different concentrations. The highest concentration of Pb (15.5mg/kg) in the study sites was found in Omu-Aran which was statistically the same with the concentration of Pb (15.0mg/kg) in Ipee followed by Odo-Ore (10.0mg/kg) while the lowest concentration was recorded in Aran-Orin (3.0mg/kg) at $p<0.05$. The concentrations of Pb were found to be higher in the dumpsite than the concentration of Pb in the Control (Table 2). The trend of Pb concentrations is as follows- Omu-Aran = Ipee > Odo-Ore > Offa > Oko-Olowo >Aran-Orin > Control

It was found that the content of Cd in the study sites at 0m differed significantly at $p<0.05$. The trend of Cd concentrations is as follows; Ipee = Oko-Olowo = Omu-Aran = Control > Odo-Ore = Offa = Aran-Orin.

When the mean of Cd values were subjected to DMRT which showed that Oko-Olowo, Omu-Aran and Ipee dumpsites Cd contents were statistically the same but were statistically greater than the Cd content in Offa, Odo-Ore and Aran-Orin at $p<0.05$. The concentrations of Cd were the same with the Control sites (Table 2).

Table 2 shows that the highest Zn concentration at 0m was found in Offa (300mg/kg) while the lowest concentration was found in Oko-Olowo (205mg/kg) (Table 2). When the mean Zn values were subjected to DMRT, it showed that there were significant differences among all the locations and that the Zn contents were statistically different at all the locations at $p\leq0.05$. The concentrations of Zn in the locations were found to be statistically higher than the concentration

in the Control site at p≤0.05 (Table 2). The trend of Zn concentrations is as follows: Offa > Odo-Ore > Ipee > Aran-Orin > Omu-Aran > Oko-Olowo > Control

It was found that the highest Ni concentration at 0 m was found in Aran-Orin (6.0mg/kg) while the lowest was at Oko-Olowo and Ipee (1.0mg/kg). The mean of these values when subjected to DMRT showed that Ni was statistically greater in Aran-Orin than in Omu-Aran which in turn was greater than in Offa and Odo-ore which were statistically the same and greater in Oko-Olowo and Odo-Ore which were statistically the same at p≤0.05. The concentrations of Ni were found to be statistically higher in all the locations than the concentration of Ni in the Control sites (Table 2).The trend of Ni concentrations is as follows**:** Aran-Orin > Omu-Aran > Offa = Odo-Ore > Ipee = Oko-Olowo > Control

It was further found that the highest concentration of Cu at 0 m was found in Ipee (41.0 mg/kg) while the lowest concentration was found in Aran-Orin (5.0 mg/kg). When the mean Cu values were subjected to DMRT which showed that Cu was statistically greater in Ipee site than in Omu-Aran site which was statistically greater in Oko-Olowo, Offa and Odo-Ore sites which were statistically the same but were statistically higher than the Cu contents in Aran-Orin site at p≤0.05. The Cu concentrations were found to be higher in all the sites than at the Control sites (Table 2). The trend of Cu concentrations is as follows: Ipee > Omu-Aran > Odo-Ore = Offa = Oko-Olowo > Aran-Orin > Control

Table 2 further shows that the highest Fe concentration at 0 m was found in Oko-Olowo site (6800mg/kg) while the lowest concentration was found in Aran-Orin (2950mg/kg). Separation of the mean Fe values in the study sites revealed that the values of Fe in Oko-Olowo was statistically greater than the value of Fe in Ipee site which was statistically greater than the value

of Fe in Omu-Aran, Offa and Odo Ore sites while the least was at Aran-Orin at $p<0.05$.The Fe concentrations were found to be higher in all the locations than in the Control sites except for Aran-Orin site that was lower than the Control (Table 2). The trend of Fe concentrations is as follows: Oko-Olowo > Ipee > Omu-Aran > Offa > Odo-Ore > Aran-Orin > Control

Table 2 shows the heavy metal concentrations of soil samples collected from all the study sites at 10m. The heavy metals were present in different concentrations. It was found that the highest concentration of Pb (75.0mg/kg) was found in Oko-Olowo dumpsite while the lowest concentration of Pb (1.5mg/kg) was found in Odo-Ore. The mean of the values when subjected to DMRT showed that Pb was statistically greater in Oko-Olowo than in Ipee, Pb in Ipee was statistically greater than Pb in Offa, followed by Omu-Aran, and then Aran-Orin which was statistically greater than in Odo-Ore at $p<0.05$ (Table 2). The Pb concentrations were found to be higher in all the locations than in the Control sites except for Odo-Ore that has the same concentration statistically with the Control sites (Table 2). The trend of Pb concentrations is as follows: Oko-Olowo > Offa > Ipee > Omu-Aran > Aran-Orin > Odo-Ore = Control

It was found that the highest Cd concentration at 10m away (2.5 mg/kg) was found at Oko-Olowo dumpsite while the lowest concentration (0.5mg/kg) was found in Omu-Aran, Offa, Odo-

TABLE 2: Heavy metal contents of soil samples (mg/kg)

DISTANCE	LOCATION	Lead (Pb)	Cadmium (Cd)	Zinc(Zn)	Nickel(Ni)	Copper(Cu)	Iron (Fe)
0meter (Centre)	Oko-Olowo	5.0±0.5^{d}	0.5 ±0.1^{a}	205±10^{f}	1.0± 0.3^{d}	6.0±0.1^{c}	6800 ±2.0^{a}
	Omu Aran	15.5±0.5^{a}	0.5± 0.1^{a}	250±5.0^{e}	4.0± 0.1^{b}	8.5±0.1^{b}	6250 ±1.0^{c}
	Offa	7.5±0.1^{c}	0.0±0.0^{b}	300±2.0^{a}	1.5 ±0.1^{c}	6.0 ±0.5^{c}	5250 ±1.0^{d}
	Odo-Ore	10.0±0.5^{b}	0.0±0.0^{b}	280±10.0^{b}	1.5 ±0.1^{c}	6.0± 0.5^{c}	3600 ±2.0^{e}
	Aran Orin	3.0±0.1^{e}	0.0±0.0^{b}	260±1.0^{d}	6.0 ± 0.1^{a}	5.0 ±0.3^{d}	2950 ±1.0^{f}
	Ipee	15.0±0.5^{a}	0.5± 0.2^{a}	270±2.0^{c}	1.0 ±0.2^{d}	41.0±0.5^{a}	6450 ±5.0^{b}
	Oko-Olowo	75.0±1.0^{a}	2.5± 0.1^{a}	1205±4.0^{a}	1.33±0.57^{a} ^{b}	225.0±2.0^{a}	6750 ±2.0^{a}
	Omu Aran	6.5±0.1^{d}	0.5± 0.1^{b}	205±1.0^{c}	0.5 ± 0.1^{c}	6.5 ± 0.0^{d}	5700 ±3.0^{c}

	Offa	15.0±0.4[c]	0.5± 0.1[b]	435±0.0[b]	1.0 ±0.1[b]	81.0 ±2.0[b]	6600 ±2.0[b]
	Odo-Ore	1.5±0.1[f]	0.5 ±0.1[b]	94.0 0.5[e]	0.0 ±0.0[d]	3.5± 0.1[e]	3300 ±3.0[e]
10meters	Aran Orin	5.5±0.1[e]	0.5 ± 0.0[b]	4.5±0.4[c]	1.5± 0.1[a]	14.3±0.76[c]	5700 ±1.0[c]
	Ipee	30.0±0.5[b]	0.5 ± 0.2[b]	116.0±1.0[d]	0.0 ±0.0[d]	4.5 ± 0.1[de]	4200 ± 1.0[d]
	Oko-Olowo	30.3±0.76[a]	0.5± 0.1[a]	410±1.0[a]	1.5 ± 0.4[b]	6.5 ±0.2[c]	1480 0 ±5.0[b]
	Omu Aran	5.5±0.2[c]	0.5 ± 0.1[a]	245± 1.0[c]	1.0 ± 0.1[c]	7.5 ± 0.2[b]	7850 ±5.0[c]
20meters	Offa	27.0±0.3[b]	0.0± 0.0[b]	325± 2.0[b]	4.5 ±0.1[a]	20.5±0.5[a]	1965 0 ±4.0[a]
	Odo-Ore	3.5±0.2[d]	0.5 ±0.0[a]	210 ±2.0[e]	0.5± 0.2[d]	0.5± 0.1[e]	2187 ±2.0[f]
	Aran Orin	4.0±0.2	0.5 ± 0.2[a]	220± 1.0[d]	1.5± 0.2[b]	6.0±0.2[c]	7300

		d					±2.0[d]
	Ipee	0.0±0.0[e]	0.5 ± 0.1[a]	116.0±1.0[f]	0.0 ±0.0[e]	4.5 ± 0.4[d]	3250 ± 1.0[e]
	Oko-Olowo	2.0±0.1[d]	0.0± 0.0[b]	290 ±3.0[b]	0.5 ± 0.2[c]	4.5±0.1[f]	4050 ±1.0[e]
	Omu Aran	5.0±0.5[c]	0.5 ± 0.1[a]	195± 1.0[d]	0.5 ± 0.2[c]	5.5 ± 0.2[d]	6650 ±1.0[b]
30meters	Offa	8.5±0.1[b]	0.5± 0.2[a]	65 ± 1.0[e]	1.0 ±0.3[b]	10.0 ±0.2[a]	7550 ±3.0[a]
	Odo-Ore	10.5±0.5[a]	0.5 ±0.0[a]	240 ±1.0[c]	0.0 ±0.0[d]	5.0± 0.5[e]	4300 ±5.0[d]
	Aran Orin	8.4±0.1[b]	0.5 ± 0.1[a]	480± 2.0[a]	2.0± 0.2[a]	7.5±0.2[b]	1390 ±1.0[f]
	Ipee	0.5±0.1[e]	0.0± 0.0[b]	45.0± 45[c]	1.0 ±0.1[b]	6.0 ± 0.2[c]	6600 ± 1.0[c]
	Oko-Olowo	42.0±1.0[a]	1.0± 0.3[b]	1290±3.0[a]	4.0 ± 0.1[b]	31.0±0.5[a]	5550 ±1.0[d]
	Omu Aran	8.0±0.0[d]	0.0± 0.0[d]	134.8±0.76[e]	0.5 ± 0.1[cd]	6.5 ± 0.2[d]	1510 0

40meters							±3.0[b]
	Offa	0.0±0.0[e]	0.5± 0.2[c]	65± 2.0[c]	1.0 ±0.3[c]	1.5 ±0.2[f]	5100 ±1.0[e]
	Odo-Ore	10.0±0.5[c]	0.5 ±0.1[c]	270 ±2.0[d]	1.0 ±0.1[c]	7.5± 0.1[c]	5950 ±2.0[c]
	Aran Orin	8.0±0.1[d]	0.5 ± 0.1[c]	445± 1.0[c]	0.0± 0.0[d]	6.0±0.1[c]	2085 0 ±3.0[a]
	Ipee	26.0±0.5[b]	4.0 ± 0.2[a]	475 ±2.0[d]	19.5±0.6[a]	16.0 ±0.1[b]	4850 ± 5.0[f]
Control	Oko-Olowo	1.5±0.2[a]	0.5± 0.1[a]	121.5±0.5[b]	0.5 ± 0.2[a]	2.5±0.1[a]	2850 ±2.0[b]
	Offa	0.5±0.2[b]	0.5 ± 0.1[a]	195± 2.0[a]	0.0 ± 0.0[b]	2.5 ± 0.1[a]	3550 ±1.0[a]
EU permissible limits		300	3.0	300	75	140	NM

Values with different superscripts along the column are significantly different at $p < 0.05$

Ore, Aran-Orin and Ipee sites. When the mean were subjected to DMRT, it showed that the Cd concentration in Oko-Olowo dumpsites was statistically greater than the value of Cd in Omu-Aran, Offa, Odo-Ore, Aran-Orin and Ipee which were statistically the same at $p \leq 0.05$(Table 2). The Cd concentrations in the dumpsites were the same with the Cd concentration of the Control

sites (Table 2), except Oko-Olowo that has a higher concentration of 2.5mg/kg. The trend of Cd concentrations is as follows: Oko-Olowo > Omu-Aran = Offa = Odo-Ore = Aran-Orin = Ipee = Control

Table 2 shows that the highest Zn concentration at 10m away (1205 mg/kg) was at Oko-Olowo dumpsite while the lowest Zn concentration (4.5mg/kg) was found in Aran-Orin dumpsite. When the mean of Zn values were subjected to DMRT, it was found that the Zn content in Oko-Olowo dumpsite was statistically greater than the Zn content in Offa dumpsite which was statistically greater that the Zn content in Omu-Aran dumpsite, followed by Ipee dumpsite, which was statistically greater than the Zn content in Aran-Orin site at $p \leq 0.05$. That is there were significant differences among all the locations. The Zn concentrations in the urban dumpsites were greater than the control site while Zn concentration in the rural dumpsites were lower that the Control site (Table 2). The trend of Zn concentrations is as follows: Oko-Olowo > Offa > Omu-Aran > Ipee > Odo-Ore > Control > Aran-Orin

It was found from Table 2 that the highest Ni concentration (1.5mg/kg) was found at Aran Orin site while the lowest concentration was 0.0mg/kg (Ni was absent) in Odo-Ore site and Ipee dumpsites at 10m away from the centre of the dumpsites. When the mean value of Ni were subjected to DMRT, it was found that Ni at Aran-Orin was significantly greater than Ni in Offa and Odo Ore sites but greater than Oko-Olowo that was not significantly different from the Ni content in Ipee at $p<0.05$. The Ni concentrations in Offa and Odo-Ore were statistically the same at $p<0.05$. However, the Ni content in Aran-Orin, Omu-Aran, Offa and Odo-Ore were statistically greater than the Ni content in the control. The trend of Ni concentrations is as follows: Aran-Orin = Oko-Olowo =Offa > Omu-Aran > Control > Odo-Ore = Ipee

It was found from Table 2 that the highest Cu concentration (225.0mg/kg) was found at Oko-Olowo site while the lowest Cu concentration (3.5mg/kg) was found at Odo-Ore site. When the mean Cu values were subjected to DMRT,it was found that Cu in Oko-Olowo site was statistically greater than Cu concentration in Offa site which was in turn statistically higher than in Aran-Orin which was statistically greater than the Cu content at Omu-Aran site but the Cu content in Ipee was not significantly different from the Cu content in Omu-Aran and Odo-Ore site at $p<0.05$ (Table 2). The Cu concentrations were found to be higher in all the locations than the control sites (Table 2). The trend of Cu concentrations is as follows: Oko-Olowo > Offa > Aran-Orin > Omu-Aran > Ipee > Odo-Ore > Control**.**

Table 2 shows that the highest Fe concentration (6750mg/kg) was found at Oko-Olowo site while the lowest Fe concentration (3300mg/kg) was found at Odo-Ore. The mean values were subjected to DMRT and was found that Fe was statistically greater in Oko-Olowo than in Offa which was significantly different from Omu-Aran and Aran-Orin sites which were statistically the same and were statistically greater in Ipee and Odo-Ore at $p<0.05$. The Fe concentrations were found to be higher in all the locations except in Odo-Ore than the Fe concentration in the Control site (Table 2). The trend of Fe concentrations is as follows: Oko-Olowo > Offa> Aran-Orin = Omu-Aran > Ipee > Odo-Ore > Control

Table 2 shows the heavy metal concentrations of soil in the study sites at 20m away from the centre of the sites. The trend of Pb concentrations is as follows: Oko-Olowo > Offa > Omu-Aran > Odo-Ore = Aran-Orin > Control > Ipee**.** It was found that the highest Pb concentration (30.3mg/kg) was recorded in Oko-Olowo site while the lowest Pb concentration (3.5mg/kg) was found in Odo-Ore site. The mean Pb values were subjected to DMRT,it was found that Pb in Oko-Olowo was statistically greater than Pb content in Offa site which was statistically greater

than Pb content in Omu-Aran site which in turn was statistically greater than the Pb content in Odo-Ore and Aran-Orin site which were statistically the same but statistically greater than the Pb content in Ipee at $p<0.05$ (Table 2). The concentrations of Pb were found to be higher in all the locations (except in Ipee where Pb was absent) than at the Control site (Table 2).

Table 1 further shows that Cd content of soil from Oko-Olowo, Omu-Aran, Odo-Ore, Aran-orin and Ipee were statistically the same but were statistically greater than the Cd content in Offa site at $p<0.05$. The Cd concentrations were found to be the same with those of the Control site except for Offa (Table 2). The trend of Cd concentrations is as follows: Oko-Olowo = Aran-Orin = Omu-Aran = Ipee = Odo-Ore = Control > Offa

The highest Zn concentration for Zn (410 mg/kg) was found in Oko-Olowo site while the lowest (116mg/kg) was found in Ipee site. The mean were subjected to DMRT and it was found that there were significant differences among all the locations and the Zn content was statistically different at all the locations at $p<0.05$. The Zn concentrations were found to be higher in all the locations than the Control (Table 2) except for Ipee where the Zn concentration was lower than the Control (Table 2). The trend of Zn concentrations is as follows: Oko-Olowo > Offa > Omu-Aran > Aran-Orin > Odo-Ore > Control > Ipee.

It was found that the highest Ni concentration at 20 m (4.5mg/kg) was found in Offa site while the lowest was found in Odo-Ore site (0.5mg/kg). The mean Ni values were subjected to DMRT, and it was found that Ni was statistically greater in Offa than in Aran-Orin and Oko-Olowo which were statistically the same but statistically greater than the Ni content in Omu-Aran and Odo-Ore which were statistically different at $p<0.05$ (Table 2). The trend of Ni concentrations is as follows: Offa> Aran-Orin = Oko-Olowo > Omu-Aran > Odo-Ore > Ipee > Control

Table 2 shows the highest Cu concentration (20.5mg/kg) was found in Offa site while the least was found in Odo-Ore site. When the mean Cu concentration were subjected to DMRT, it was found that Cu was statistically greater in Offa site than in Omu-Aran site which was statistically greater than Oko-Olowo and Aran-Orin sites which were statistically the same but were statistically greater than Ipee which were significantly different from Odo-Ore at $p<0.05$. The Cu concentrations were found to be higher in all the locations than in the Control (Table 2) except for Odo-Ore that was lower than the Control. The trend of Cu concentrations is as follows: Offa > Omu-Aran > Aran-Orin =Oko-Olowo > Ipee > Control > Odo-Ore

Table 2 shows that the highest Fe concentration (19650mg/kg) was found in Offa while the lowest Fe concentration (2187mg/kg) was found in Odo-Ore. When the mean Fe values were subjected to DMRT, it was found that there were significant differences among all the locations and the Fe contents were statistically different at all the locations at $p<0.05$. The Fe concentrations were found to be higher in all the locations except at Odo-Ore and Ipee that had lower Fe concentration than the Control (Table 2). The trend of Fe concentrations is as follows:

Offa > Oko-Olowo > Omu-Aran >Aran-Orin.> Control > Ipee > Odo-Ore

Table 2 shows the heavy metal concentrations of soil in the study sites at 30m away from the centre of the dumpsites. From Table 2, it was found that the highest Pb concentration (10.5mg/kg) in the study sites was recorded in Odo-Ore site while the lowest concentration was in Ipee site (0.5mg/kg). When the mean Pb values were subjected to DMRT, it was found that there were significant differences among all the locations but Pb contents in Offa and Aran-Orin sites were statistically the same at $p<0.05$. The Pb concentrations were found to be higher in all the dumpsites than in the Control (Table 2) except for Ipee that was similar to that of the Control

(Table 2). The trend of Pb concentrations is as follows: Odo-Ore > Offa = Aran-Orin > Omu-Aran > Oko-Olowo > Control > Ipee.

Table 2 further shows that Cd content of the soil from Omu-Aran, Offa, Odo-Ore and Aran-Orin sites (0.5 mg/kg) were the highest and were statistically the same but significantly different from the Cd content of Ipee and Oko-Olowo(0.0mg/kg) sites at $p<0.05$. The Cd concentrations were found to be the same with those of the Control (Table 2) except in Oko-Olowo and Ipee where Cd was absent. The trend of Cd concentrations is as follows: Omu-Aran = Offa = Odo-Ore = Aran-Orin > Control > Oko-Olowo = Ipee

It was found from Table 2 that the highest Zn concentration (480 mg/kg) was found in Aran - Orin site while the lowest concentration was found in Ipee site (45 mg/kg). When the mean values were subjected to DMRT, it was found that there were significant differences among all the locations and that the Zn contents were statistically different in all the locations at $p<0.05$. The Zn concentration in Omu-Aran was the same statistically with the Control (Table 2) while the Zn contents in Offa and Ipee were lower than in the Control (Table 2). The trend of Zn concentrations is as follows: Aran-Orin > Oko-Olowo > Odo-Ore > Omu-Aran > Control > Offa > Ipee

The highest Ni concentration (2.0mg/kg) was found in Aran-Orin site while the lowest concentration was found in Odo-Ore site (0.0mg/kg) that is Ni was absent in Odo-Ore. When the mean values were subjected to DMRT, it was found that there were significant differences among all the locations and the Zn contents were statistically different in all locations except Oko-Olowo and Omu-Aran that were statistically the same at $p<0.05$. The Ni concentrations were found to be higher in all the locations than in the Control (Table 2) except for Oko-Olowo,

Omu-Aran and Odo-Ore that were similar to those in the Control (Table 2). The trend of Ni concentrations is as follows: Aran-Orin > Offa = Ipee > Oko-Olowo = Omu-Aran. > Control > Odo-Ore.

Table 2 further shows that the highest Cu concentration (10.0mg/kg) was found in Offa site while the lowest was recorded in Oko-Olowo site (4.5mg/kg). When the mean Cu values were subjected to DMRT, it was found that there were significant differences among all the locations and the Cu content were statistically different in all the locations at $p<0.05$. The Cu concentrations were found to be higher in all locations than the Cu concentration in the Control (Table 2). The trend of Cu concentrations is as follows: Offa > Aran-Orin > Ipee > Omu-Aran > Odo-Ore > Oko-Olowo > Control

It was found that the highest Fe concentration (7550 mg/kg) was found in Offa site at 30m away while the lowest concentration was found in Aran-Orin site (1390 mg/kg). When the mean values were subjected to DMRT,it was found that there were significant differences among all the locations and the Fe contents were statistically different in all locations at $p<0.05$. The Fe concentrations were found to be higher in all the locations (except for Aran-Orin) than in the Control sites (Table 2). The trend of Fe concentrations is as follows: Offa > Omu-Aran > Ipee > Odo-Ore > Oko-Olowo > Control > Aran-Orin

Table 2 shows the heavy metal concentrations of soil in the study sites at 40metres away from the centre of the dumpsites. It was found that the highest Pb concentration at this point (40 m) away (42.0mg/kg) was recorded in Oko-Olowo site while the lowest Pb concentration (0.0 mg/kg) was found in Offa. When the mean values were subjected to DMRT, it was found that there were significant differences in the Pb contents among all the locations and the Pb contents

were not statistically the same at $p<0.05$. The Pb concentrations were found to be higher in all the locations except for Offa where Pb was absent than the Pb concentration in the Control sites (Table 2). The trend of Pb concentrations is as follows: Oko-Olowo > Ipee > Odo-Ore > Omu-Aran = Aran-Orin.> Control > Offa

It was found that the highest Cd concentration (4.0mg/kg) was found a 40m away from the centre in Ipee site while the lowest Cd concentration was found in Omu-Aran site (0.0 mg/kg). When the mean Cd values were subjected to DMRT,it was found that there were significant differences among the locations and that Cd content in Offa, Odo-Ore, and Aran-Orin sites were statistically the same, but significantly different from the Cd value in Omu-Aran, Ipee and Oko-Olowo sites at $p\leq0.05$. The Cd concentrations in the locations were found to be the same with the Cd concentration in the Control sites (Table 2) except for Ipee and Oko-Olowo sites that were higher than the Control sites (Table 2). The trend of Cd concentrations is as follows: Ipee > Oko-Olowo > Offa = Odo-Ore = Aran-Orin = Control > Omu-Aran.

The highest Zn concentration (1290 mg/kg) was found in Oko-Olowo site at 40m away from the centre while the lowest was found in Omu-Aran site (134.8 mg/kg). When the mean Zn values were subjected to DMRT, it was found that there were significant differences among the locations and that the Zn contents in Offa and Aran-Orin sites were statistically the same at $p\leq0.05$. The Zn concentrations were found to be higher in all the locations than the Control sites (Table 2) except for Omu-Aran and Offa sites that had lower Zn concentrations than the Control sites (Table 2). The trend of Zn concentrations is as follows: Oko-Olowo > Ipee > Aran-Orin > Odo-Ore > Control > Omu-Aran > Offa

The highest Ni concentration (19.5 mg/kg) was found in Ipee site at 40m away from the centre while the lowest (0.0 mg/kg) was found in Aran-Orin site. When the mean Ni values were subjected to DMRT, it was found that there were significant differences among the locations Offa and Odo-Ore sites had higher Ni concentrations but were not significantly different from Omu-Aran site at $p \leq 0.05$. The Ni concentrations were found to be higher in all the locations (Table 2) except for Omu-Aran and Aran-Orin sites that had the same Ni concentration with those from the Control sites (Table 2). The trend of Ni concentrations is as follows: Ipee > Oko-Olowo > Odo-Ore = Offa > Omu-Aran = Control > Aran-Orin.

The highest Cu concentration (31.0 mg/kg) was found in Oko-Olowo site at 40m away from the centre while the lowest (1.5mg/kg) was found in Offa site. The Cu concentrations were significantly different across the sites at $p < 0.05$. The Cu concentrations were found to be higher in all the locations except in Offa that was lower than the Control site (Table 2). The trend of Cu concentrations is as follows: Oko-Olowo > Ipee > Odo-Ore > Omu-Aran > Aran-Orin > Control > Offa.

The highest Fe concentration (20850.0mg/kg) was found in Aran-Orin site at 40m away from the centre while the lowest (4850.0mg/kg) was found in Ipee site. The Fe concentrations were significantly different across the site at $p < 0.05$. The Fe concentrations were found to be higher in all the locations than the Control site (Table 2). The trend of Fe concentrations is as follows: Aran-Orin > Omu-Aran > Odo-Ore > Oko-Olowo > Offa > Ipee > Control

Table 3 shows the heavy metal contents of plants collected at different locations from the dumpsites. Table 2 shows the heavy metal concentrations of plants collected from the study sites at 0 metres. The highest Pb concentration (7.0 mg/kg) was found in plants collected from Oko-

Olowo site while Pb was absent in plants growing in Aran-Orin and Ipee sites. There was no significant differences between the Pb content in Omu-Aran and Odo-Ore sites at $p<0.05$. The Pb concentrations in plants growing at different locations were higher than those from the Control site (Table 3) except for those collected at Aran-Orin and Ipee where Pb was absent. The trend of Pb concentrations is as follows: Oko-Olowo > Offa> Omu-Aran > Odo-Ore > Aran-Orin =Ipee = Control

The Cd contents of plants were found to be statistically the same however Cd was absent in plants growing at Ipee site. The Cd concentrations were found to be the same with those of the Control sites (Table 3) except for plants collected from Ipee where Cd was absent. The trend of Cd concentrations is as follows: Oko-Olowo = Offa = Omu-Aran = Odo-Ore = Aran-Orin > Ipee = Control

The highest Zn concentration (129 mg/kg) was found in plants collected from Oko-Olowo site while the lowest (31.0 mg/kg) was found in those collected from Aran-Orin site. There were significant differences in Zn contents at $p<0.05$ across the sites. The Zn concentrations were found to be higher in the Control (Table 3) than at the experiment locations except for Oko-Olowo and Omu-Aran where the plants contained higher Zn concentration than the Control sites (Table 3). The trend of Zn concentrations is as follows: Oko-Olowo > Omu-Aran > Odo-Ore > Offa > Control > Ipee > Aran-Orin.

The highest Ni concentration (5.5 mg/kg) was found in plants collected from Aran-Orin site while the lowest (0.0 mg/kg) was found in plants collected from Ipee (that is Ni was absent in the plants). There were significant differences in the Ni concentrations in plants collected from all the locations but Ni contents at Offa and Odo-Ore were statistically the same at $p<0.05$. The Ni

concentrations were found to be the same with the Control sites except for plants collected from Oko-Olowo and Aran-Orin sites that had greater Ni concentration than the Control (Table 3). The trend of Ni concentrations is as follows: Aran-Orin > Oko-Olowo > Offa = Odo-Ore > Control > Omu-Aran = Ipee.

The highest Cu concentration (7.5 mg/kg) was found in plants collected at 0m of the dumpsite from Oko-Olowo site while the lowest (1.0mg/kg) was found in plants collected from Aran-Orin site. There were significant differences among the locations at $p<0.05$. The Cu concentrations were found to be higher in the experimental locations than at the Control sites (Table 3). The trend of Cu concentrations is as follows: Oko-Olowo > Offa > Odo-Ore > Ipee > Control > Omu-Aran > Aran-Orin

Table 3 shows that the highest Fe concentration (4300 mg/kg) was found in plants collected from Ipee site while the lowest (770 mg/kg) was found in plants growing in Aran-Orin site. There were significant differences in the heavy metal concentrations among the locations. The Fe concentrations were found to be higher in the locations than plants in the Control sites (Table 3). The trend of Fe concentrations is as follows: Ipee > Offa > Oko-Olowo > Odo-Ore > Omu-Aran > Aran-Orin > Control.

Table 3 shows the heavy metal concentrations of plant samples collected from study sites at 10meters away from the centre of the dumpsite. The heavy metals were present in different concentrations. The highest Pb concentration (4.0 mg/kg) was found in plants collected from Oko-Olowo site while the lowest (0.0 mg/kg) was found in plants collected from Offa, Odo-Ore, Aran-Orin and Ipee sites. That is, Pb was absent in these locations and there were no significant differences among them at $p<0.05$.No Pb was detected in plants collected from Offa, Ipee, Odo-Ore, Aran-Orin, but present in small quantities in plants collected from Oko-Olowo and Omu-

Aran. The trend of Pb concentrations is as follows: Oko-Olowo > Omu-Aran > Offa = Odo-Ore = Aran-Orin =Ipee = Control

It was found that there were no significant differences among the Cd contents in plants collected from Oko-Olowo, Omu-Aran, Offa, Odo-Ore and Aran-Orin sites and were found to be statistically greater than the Pb content in Ipee at $p<0.05$. The trend of Cd concentrations is as follows: Oko-Olowo = Omu-Aran = Offa = Odo-Ore = Aran-Orin > Ipee = Control

Table 3 further shows that the highest Zn concentration (88.0 mg/kg) was found in plants collected from Oko-Olowo site while the lowest (38.0mg/kg) was found in plants collected from Ipee site. There were significant differences among the locations at $p<0.05$. The Zn concentrations in the Control sites and locations were within the same range except for plants collected from Ipee and Aran-Orin sites that had lower Zn content than the Control (Table 3). The trend of Zn concentrations is as follows: Oko-Olowo > Offa > Omu-Aran = Odo-Ore > Control > Aran-Orin > Ipee

The highest Ni concentration (5.0 mg/kg) was found in plants growing in Odo-Ore site while the lowest (0.0 mg/kg) was found in plants growing in Omu-Aran and Aran-Orin sites. There were no significant differences between the Ni content in Omu-Aran and Aran-Orin at $p<0.05$. The concentrations of plants from the dumpsites were found to be within the same range with those plants from the Control (Table 3) except for plants from Oko-Olowo and Odo-Ore sites that had greater Ni contents than the Control. Ni was absent in plants from Omu-Aran and Aran-Orin sites (Table 3). The trend of Ni concentrations is as follows: Odo-Ore > Oko-Olowo > Offa = Ipee > Control > Omu-Aran > Aran-Orin.

The highest Cu concentration (6.5 mg/kg) was found in plants collected from Oko-Olowo site while the lowest (1.0 mg/kg) was found in Ipee plants. There were significant differences in the

Cu contents in plants collected from all the locations at $p<0.05$. The Cu concentrations of plants in the dumpsites were higher than those at the Control (Table 3). The trend of Cu concentrations is as follows: Oko-Olowo > Aran-Orin > Omu-Aran > Offa > Control > Odo-Ore > Ipee

Table 3 further shows the highest Fe concentration (3250 mg/kg) was found in plants collected from Odo-Ore site while the lowest concentration (215 mg/kg) was found in Aran-Orin plants. The Fe contents of the plants were statistically different in all locations at $p<0.05$. The Fe concentrations in all the locations were higher than those from the Control except for plants from

TABLE 3: Heavy metal contents (mg/kg) of plant samples collected from the six dumpsites

DISTANCE	LOCATION	Plant	Lead (Pb)	Cadmium (Cd)	Zinc(Zn)	Nickel(Ni)	Copper(Cu)	Iron (Fe)
0meters (centre)	Oko-Olowo	*Zea mays*	7.0±1.0^{a}	0.5± 0.1^{a}	129 ±2.0^{a}	3.5 ± 0.1^{b}	7.5±0.2^{a}	3700 ±1.0^{c}
	Omu Aran	*Mangifera indica*	1.0 ± 0.1^{c}	0.5± 0.3^{a}	121 ± 0.5^{b}	0.0 ± 0.0^{d}	2.0 ± 0.1^{e}	2850±1.0^{e}
	Offa	*Commelina diffusa*	4.5±0.2^{b}	0.5± 0.2^{a}	66± 0.3^{d}	0.5 ±0.2^{c}	6.0 ±0.1^{b}	3750 ±5.0^{b}
	Odo-Ore	*Amarantus spinosus*	0.5 ± 0.1^{cd}	0.5 ±0.2^{a}	70 ±2.0^{c}	0.5 ±0.2^{c}	5.5± 0.1^{c}	3000 ±1.0^{d}
	Aran Orin	*Tithonia diversifolia*	0.0± 0.0^{d}	0.5 ± 0.1^{a}	31± 0.5^{f}	5.5± 0.2^{a}	1.0±0.1^{f}	770 ±5.0^{f}
	Ipee	*Sida rhombifolia*	0.0±0.0^{d}	0.0 ± 0.0^{b}	33.5 ±2.0^{d}	0.0±0.0^{d}	3.5±0.1^{d}	4300 ± 3.0^{a}
10metres	Oko-Olowo	*Synedrella nodiflora.*	4.0±0.2^{a}	0.5± 0.2^{a}	88±2.0^{a}	1.0± 0.1^{b}	6.5±0.2^{a}	2750 ±5.0^{b}
	Omu Aran	*Cyperus rotundus*	1.5 ± 0.2^{b}	0.5± 0.0^{a}	62±1.0^{c}	0.0 ± 0.0^{d}	4.5 ± 0.2^{c}	2250±0.0^{c}
	Offa	*Schwenckia americana*	0.0±0.0^{c}	0.5± 0.1^{a}	82.5± 0.5^{b}	0.5 ±0.2^{c}	3.5±0.2^{d}	520 ±1.0^{e}
	Odo-Ore	*Sida acuta*	0.0±0.0^{c}	0.5 ±0.1^{a}	59.5±0.5^{c}	5.0 ±0.2^{a}	1.5± 0.2^{e}	3250 ±1.0^{a}
	Aran Orin	*Sida acuta*	0.0± 0.0^{c}	0.5 ± 0.1^{a}	41±2.0^{d}	0.0± 0.0^{d}	5.0±0.1^{b}	215±2.0^{f}
	Ipee	*Synedrella nodiflora*	0.0±0.0^{c}	0.0 ± 0.0^{b}	38±2.0^{e}	0.5±0.1^{c}	1.0±0.0^{f}	695± 3.0^{d}
20metres	Oko-Olowo	*Ageratum conizoides*	6.5±0.1^{a}	0.5± 0.0^{a}	132±0.2^{a}	0.0± 0.0^{d}	15±0.5^{a}	2250 ±2.0^{b}
	Omu Aran	*Perostis indica*	0.0±0.0^{d}	0.5± 0.2^{a}	16±1.0^{f}	0.0 ± 0.0^{d}	1.5 ± 0.1^{d}	260±5.0^{e}
	Offa	*Aspilia africana*	0.0±0.0^{d}	0.0±0.0^{b}	30.5± 0.5^{d}	1.0 ±0.1^{b}	3.0±0.1^{c}	460 ±5.0^{c}
	Odo-Ore	*Amarantus spinosus*	4.5±0.2^{b}	0.5 ±0.1^{a}	130.5±0.6^{b}	1.5±0.2^{a}	3.0± 0.3^{c}	2700 ±2.0^{a}
	Aran Orin	*Sida acuta*	0.0± 0.0^{d}	0.5 ± 0.2^{a}	41±1.0^{d}	0.0± 0.0^{d}	5.0±0.1^{b}	215±2.0^{f}
	Ipee	*Sida rhomboflora*	1.0±0.1^{c}	0.0 ± 0.0^{b}	21±0.3^{e}	0.5±0.1^{c}	1.5±0.1^{d}	320± 1.0^{d}

	Oko-Olowo	*Ageratum conizoides*	1.0±0.4^{c}	0.5± 0.0^{a}	65.5±0.8^{b}	0.5± 0.1^{c}	9.5±0.6^{a}	2200 ±10.0^{c}
30metres	Omu Aran	*Brachlaria deflesa*	2.0±0.2^{b}	0.0± 0.0^{b}	34±0.4^{d}	0.5± 0.2^{c}	3.5 ± 0.1^{d}	700±6.0^{e}
	Offa	*Talinum triangulare*	2.0±0.2^{d}	0.0±0.0^{b}	310± 0.5^{a}	1.0 ±0.1^{b}	8.0±0.4^{b}	4950±5.0^{a}
	Odo-Ore	*Cynodon dactylon*	6.9±0.5^{a}	0.5 ±0.1^{a}	61.5±0.5^{c}	0.5±0.2^{c}	3.5± 0.3^{c}	3950 ±5.0^{b}
	Aran Orin	*Sida acuta*	0.0± 0.0^{d}	0.5 ± 0.2^{a}	27.5±1.3^{e}	1.5± 0.2^{a}	0.0±0.0^{f}	425±5.0^{e}
	Ipee	*Cassia fistula*	0.0±0.0^{d}	0.5 ± 0.2^{a}	19.5±0.5^{f}	0.5±0.2^{c}	2.0±0.3^{e}	195± 1.0^{f}
	Oko-Olowo	*Hyphobia heterophylla*	2.5±0.3^{a}	0.5 ±0.0^{a}	98.5±0.5^{a}	0.5± 0.2^{b}	3.5±0.3^{a}	2400 ±40.0^{b}
	Omu Aran	*Digitaria nuda*	0.0±0.0^{d}	0.5 ±0.0^{a}	26.5±0.6^{e}	1.5± 0.1^{a}	1.5 ± 0.2^{d}	585±3.0^{d}
40metres	Offa	*Eragrostis tenella*	0.0±0.0^{d}	0.5 ±0.1^{a}	60.5± 0.5^{c}	0.0±0.0^{c}	2.5±0.1^{bc}	530±3.0^{d}
	Odo-Ore	*Cyperus esculentus*	1.5±0.2^{c}	0.5 ±0.1^{a}	68.0±1.0^{b}	0.0±0.0^{c}	2.0± 0.3^{cd}	3700 ±3.0^{a}
	Aran Orin	*Synedrella nodiflora*	0.0± 0.0^{d}	0.5 ± 0.2^{a}	40.9±1.10^{d}	0.5± 0.1^{b}	2.7±0.4^{b}	570±1.0^{c}
	Ipee	*Aspilia africana*	2.0±0.2^{b}	0.5 ± 0.2^{a}	20.0±0.2^{f}	0.5±0.2^{b}	2.0±0.3^{cd}	240± 2.0^{e}
Control	Oko-Olowo	*Cyperus esculentum*	0.0±0.0^{b}	0.0± 0.0^{b}	47.5 ±1.3^{a}	0.3± 0.5^{a}	3.0±0.5^{a}	250 ±2.1^{b}
	Offa	*Sida acuta*	2.5 ± 0.2^{a}	2.2± 0.2^{a}	28.5± 0.5^{b}	0.0 ± 0.0^{b}	0.0±0.0^{b}	320 ±2.0^{a}

Values with different superscripts along the column are significantly different at p< 0.05

Aran-Orin site (Table 3). The trend of Fe concentrations is as follows: Odo-Or2wae > Oko-Olowo > Omu-Aran > Ipee > Offa > Control > Aran-Orin

Table 3 shows the heavy metal concentrations of plants samples collected from the study sites at 20metres away from the centre of the dumpsites. From Table 3, it was found that the highest Pb concentration (6.5 mg/kg) was recorded in Oko-Olowo plants while the lowest Pb concentration (0.0 mg/kg) was found in Omu-Aran, Offa and Aran-Orin plants. That is, Pb was absent in plants from Omu-Aran, Offa and Aran-Orin. There were significant differences among all the locations at $p<0.05$. The Pb concentrations were higher in plants from the dumpsites at 20metres (Table 3) than plants from the Control, except in plants from Omu-Aran, Offa and Aran-Orin where Pb was absent. The trend of Pb concentrations is as follows: Oko-Olowo > Odo-Ore > Ipee > Omu-Aran = Offa = Aran-Orin = Control

It was found that the Cd content of the plants collected from the dumpsites (0.5 mg/kg) from Oko-Olowo, Omu-Aran, Odo-Ore and Aran-Orin sites were statistically the same but was statistically greater than the Cd content in Offa and Ipee plants that had no Cd (0.0 mg/kg) at $p<0.05$. The Cd concentrations in the locations were similar to those from the Control site except in plants from Offa and Ipee sites where Cd was absent (Table 3). The trend of Cd concentrations is as follows: Oko-Olowo = Omu-Aran = Odo-Ore = Aran-Orin > Offa =Ipee = Control

Table 3 further shows that the highest Zn content (132 mg/kg) was found in Oko-Olowo sites while the lowest (16.0 mg/kg) was found in Omu-Aran plants. There were significant differences among Zn contents in all the locations at $p<0.05$. The Zn concentrations in plants from the dumpsite were lower than those from the Control except plants from Oko-Olowo and Odo-Ore that were higher than the Control (Table 3). The trend of Zn concentrations is as follows: Oko-Olowo > Odo-Ore > Control > Aran-Orin > Offa > Ipee >Omu-Aran

Moreover, it was found that the highest Ni concentration (1.5 mg/kg) was found in Odo-Ore plants while Ni was absent in Oko-Olowo, Omu-Aran, and Aran-Orin plants at $p<0.05$. The Ni concentrations were higher in Offa and Odo-Ore sites than those plants from the Control (Table 3). The trend of Ni concentrations is as follows: Odo-Ore > Offa > Ipee > Control > Oko-Olowo = Omu-Aran = Aran-Orin

It was found that the highest Cu concentration (15.0 mg/kg) was found in plants collected from Oko-Olowo site while the lowest Cu content (1.5 mg/kg) was found in Omu-Aran and Ipee plants. Offa and Odo-Ore Cu contents were statistically the same at $p<0.05$. The Cu concentrations in plants from the dumpsites were higher than those from the Control (Table 3). The trend of Cu concentrations is as follows: Oko-Olowo > Aran-Orin > Offa = Odo-Ore = Control > Omu-Aran = Ipee

The highest Fe concentration (2700 mg/kg) was found in plants collected from Odo-Ore site while the lowest Fe contents (215 mg/kg) was found in Aran-Orin plants. The Fe concentrations in plants collected from the dumpsites were significantly different at $p<0.05$. The concentrations of Fe in plants from the dumpsites were lower in some locations while some were the same with those from the Control (Table 2). The trend of Fe concentrations is as follows: Odo-Ore > Oko-Olowo > Offa > Ipee > Omu-Aran > Control > Aran-Orin.

Table 3 shows the heavy metal concentrations of plant samples collected from the study sites at 30metres away from the centre of the dumpsites. The heavy metals were present in different concentrations. The highest Pb concentration (6.7 mg/kg) was found in plants collected from Odo-Ore site followed by plants from Omu-Aran and Offa sites which were statistically the same but greater than plants collected from Oko-Olowo while Pb was absent in Aran-Orin and Ipee sites which were statistically the same at $p<0.05$. The Pb concentrations in plants growing in the

dumpsites were higher than those collected from the Control except in Aran-Orin and Ipee sites where Pb was absent. The trend of Pb concentrations is as follows: Odo-Ore > Omu-Aran = Offa > Oko-Olowo > Aran-Orin =Ipee = Control

The highest Cd concentration (0.5 mg/kg) was found in plants collected from Oko-Olowo, Odo-Ore, Aran-Orin and Ipee sites. Cd was absent in plants collected from Offa and Omu-Aran sites which were significantly different at $p<0.05$. The Cd concentration was the same with those from the Control except in plants collected from Omu-Aran and Offa where Cd was absent. The trend of Cd concentrations is as follows: Oko-Olowo = Odo-Ore = Aran-Orin =Ipee > Omu-Aran = Offa = Control

The highest Zn concentration (310 mg/kg) was found in plants collected from 30m in Offa while the lowest (19.5 mg/kg) was found in plants collected from Ipee site. There were significant differences in the level of Zn in the plants at $p<0.05$. The Zn concentration in plants from the dumpsites were found to be within the same range as those plants from the Control except for plants collected from Offa that was higher than the Control. The trend of Zn concentrations is as follows: Offa > Oko-Olowo > Odo-Ore > Control > Omu-Aran > Aran-Orin > Ipee.

It was found from Table 3 that at 30m point from the centre of the dumpsite, the highest Ni concentration (1.5 mg/kg) was found in Aran-Orin plants while the lowest Ni contents (0.5mg/kg) was found in plants collected from Oko-Olowo, Omu-Aran, Odo-Ore and Ipee sites. There were no significant differences in the levels of Ni at these locations at $p<0.05$. The Ni concentrations of plants were found to be within the same range with those from the Control except for plants from Offa and Aran-Orin sites that were higher than the Control. The trend of Ni concentrations is as follows: Aran-Orin > Offa > Oko-Olowo = Omu-Aran = Odo-Ore =Ipee > Control

The highest Cu concentration (9.5 mg/kg) was found in plants collected from Oko-Olowo site while the lowest (0.0 mg/kg) was found in Aran-Orin plants. There were significant differences among all the locations at $p<0.05$. The Cu concentrations were found to be higher in the dumpsites than in the Control except for plants from Aran-Orin site where Cu was absent (Table 2). The trend of Cu concentrations is as follows: Oko-Olowo > Offa > Odo-Ore = Omu-Aran > Control > Ipee > Aran-Orin

The highest Fe concentration (4950 mg/kg) was found in plants from Offa site while the lowest (195.0 mg/kg) was found in Ipee site. There were significant differences among all the locations at $p<0.05$. The Fe concentrations in plants from the dumpsites were found to be lower than those from the Control (Table 3) except in Offa and Odo-Ore sites where the concentration were higher in the dumpsites than in the Control (Table 3). The trend of Fe concentrations is as follows: Offa > Odo-Ore > Oko-Olowo > Omu-Aran > Aran-Orin > Control > Ipee.

Table 3 shows the heavy metal concentrations of plant samples collected from the study sites at 40metres away from the centre of the dumpsites. The heavy metals were present in different concentrations (Table 3). Table 3 further shows that the highest Pb concentration (2.5 mg/kg) was found in plants collected from Oko-Olowo site while Pb was absent in plants from Omu-Aran, Offa and Aran-Orin sites. There were significant differences among the Pb concentrations in the plants from all the locations at $p<0.05$. The Pb concentrations were found to be higher in plants from the dumpsites than those from the Control because no Pb was detected in plants from the Control (Table 2). The trend of Pb concentrations is as follows: Oko-Olowo > Ipee > Odo-Ore > Omu-Aran = Offa = Aran-Orin =Control

It was found from Table 3 that the Cd concentration was the same in all the locations that is, there were no significant differences among the Cd contents in all the locations at $p<0.05$. The

Cd concentrations were found to be the same statistically and with those from the Control (Table 3). The trend of Cd concentrations is as follows: Oko-Olowo = Omu-Aran = Offa = Odo-Ore = Aran-Orin =Ipee ≥ Control

Table 3 shows that the highest Zn concentration (98.5mg/kg) was found in plants from Oko-Olowo site while the lowest (20.0 mg/kg) was found in plants from Ipee site. The Zn concentrations were significantly different among the plants collected from all locations at $p<0.05$. The Zn concentrations in some plants from the dumpsites were found to be higher (Oko-olowo site) than those from the Control; some were lower (plants from Omu-Aran, Aran-Orin and Ipee sites) than the Control while plants from Offa and Odo-Ore sites fell within the range (Table 3). The trend of Zn concentrations is as follows: Oko-Olowo > Odo-Ore > Offa > Control > Aran-Orin > Omu-Aran > Ipee.

The highest Ni concentration (1.5 mg/kg) was found in plants from Omu-Aran site while the lowest (0.0 mg/kg) was found in plants from Offa and Odo-Ore sites. The Ni concentrations were significantly different at $p<0.05$. The Ni concentrations in the plants from the dumpsite fell within the same range as those from the Control site (Table 3) except for Ni contents in plants from Omu-Aran site that was higher than plants from the Control site. The trend of Ni concentrations is as follows: Omu-Aran > Aran-Orin = Oko-Olowo = Ipee > Control > Offa = Odo-Ore.

The highest Cu concentration (83.5 mg/kg) was found in Oko-Olowo plants while the lowest (1.5 mg/kg) was found in Omu-Aran plants. Cu content in Offa was statistically greater than Cu content in Odo-Ore and Ipee plants which were not significantly different from the Cu content in Omu-Aran plants at $p<0.05$. The Cu concentrations were found to be higher in the dumpsites than in the Control (Table 3). The trend of Cu concentrations is as follows: Oko-

Olowo > Control > Aran-Orin > Offa > Odo-Ore = Ipee > Omu-Aran.

It was found from Table 3 that the highest Fe concentration (3700 mg/kg) was found in plants collected from Odo-Ore site while the lowest Fe concentration (240 mg/kg) was found in Ipee plants. There were significant differences among the Fe concentrations at $p<0.05$. The Fe concentration in plants from the dumpsite were found to be lower than plants from the Control sites except for plant from Odo-Ore site that was higher than the Control (Table 3). The trend of Fe concentrations is as follows: Odo-Ore > Oko-Olowo > Aran-Orin = Omu-Aran > Offa > Control > Ipee.

Table 4 shows the heavy metal contents of soil samples collected from Oko – Olowo dumpsite. The heavy metals were present in different concentrations with iron being the highest on the dumpsite. The trend of heavy metal concentrations is as follows: Fe > Zn > Cu > Pb > Ni > Cd. Cd had the lowest concentration on the Oko-Olowo dumpsite. Table 4 further shows that the concentrations of heavy metals did not show any trend with distances from the centre of the dumpsite. The concentrations of heavy metals were found to be higher than the Control with the exception of Zn that was lower at 40m than the Control from Ile-Oba in Offa (Table 4).

Table 5 shows the heavy metal contents of soil samples collected from Omu-Aran dumpsite. The heavy metals were present in different concentrations with Iron (Fe) being the highest on the dumpsite. The trend of heavy metal concentrations is as follows: Fe > Zn > Pb > Cu > Ni > Cd. The trend showed that Iron had the highest concentration in the location followed by Zn while Cd had the lowest concentration. Table 5 further shows that the concentration of heavy metals did not show any definite relationship with distances from the centre of the dumpsite. The concentrations of heavy metals were found to be higher in the dumpsite than the Control with the exception of Zn that was lower at 40m than the Control from Ile-Oba area in Offa (Table 4).

Table 6 shows the heavy metal concentrations of soil samples collected from Offa dumpsite. The heavy metals were present in different concentrations with Fe being the highest on the dumpsite. The trend of heavy metal concentrations is as follows: Fe > Zn > Cu > Pb > Ni > Cd

The trend showed that Iron had the highest concentration in the location followed by Zinc, then Copper while Cadmium was the lowest concentration. The total concentrations of heavy metals were found to be higher in the dumpsite than the Control with the exception of Zn that was lower at 30m and 40m than the Control site (Ile-Oba in Offa) (Table 6). Table 6 further shows that the concentration of heavy metals did not show any definite relationship with distances from the centre of the dumpsite.

The heavy metal contents of soil samples collected at Odo-Ore dumpsite are presented in Table 7. The heavy metals were present in different concentrations with Fe having the highest concentration (5950mg/kg). The trend of the heavy metal concentrations is as follows: Fe > Zn > Pb > Cu > Ni > Cd

The trend showed that Fe had the highest concentration in the location followed by Zinc then Lead while Cadmium had the lowest concentration. The total concentrations of heavy metals were found to be higher in the dumpsite than the control for all the heavy metal with the exception of Zn and Fe. The Zn content at 10m was lower than the Zn content in the Control site (Table 7). Iron content at 10 and 20meters were lower than the heavy metal content at the Control site (Table 7). Table 7 further shows that the concentration of heavy metals did not show any definite relationship with distances from the centre of the dumpsite.

The heavy metal contents of soil samples collected at Aran-Orin dumpsite are presented in Table 8. The heavy metals were present in different concentrations with Iron having the highest concentration (20,850mg/kg). The trend of the heavy metal concentrations is as follows: Fe > Zn

> Cu > Pb > Ni > Cd

The trend showed that Fe had the highest concentrations in the location followed by Zinc, then Copper while Cadmium had the lowest concentration. The total concentration of heavy metals were found to be higher in the dumpsite than the Control with the exception of Fe at 30metres that was lower than the Fe content at the Control sites (Table 8). Table 8 further shows that the concentration of heavy metals did not show any definite relationship with distances from the centre of the dumpsite.

The heavy metal concentrations of soil samples collected from Ipee dumpsite are presented in Table 9. The heavy metals were present in different concentrations with Iron having the highest concentration (6,600mg/kg). The trend of the heavy metal concentrations is as follows:

Fe > Zn > Pb > Cu > Ni > Cd

The trend showed that Fe had the highest concentrations in the location followed by Zinc, then Lead while Cadmium had the lowest concentration. The total concentration of heavy metals were found to be higher in the dumpsite than the control with the exception of Zinc at 10 and 20m that were lower than the Zinc content at the Control site (Table 9). The highest concentration of the heavy metals were found at the center of the dumpsite while the corresponding lowest concentration were found at 20m away from the center of the dumpsite.

TABLE 4: Heavy metal concentration (mg/kg) of soil samples from Oko-Olowo dumpsite.

Distance	Pb	Cd	Zn	Ni	Cu	Fe
0m	5.0 ± 0.5^{d}	0.5 ± 0.1^{c}	205 ± 1.0^{d}	1.0 ± 0.3^{bc}	6.0 ± 0.1^{c}	6800 ± 2.0^{b}
10m	75.0 ± 1.0^{a}	2.5 ± 0.1^{b}	1205 ± 4.0^{a}	1.3 ± 0.6^{b}	2.25 ± 2.0^{e}	6750 ± 2.0^{c}
20m	30.3 ± 0.76^{c}	0.5 ± 0.1^{c}	410 ± 1.0^{b}	1.5 ± 0.4^{b}	6.5 ± 0.2^{b}	14800 ± 5.0^{a}
30m	2.0 ± 0.1^{e}	0.0 ± 0.0^{d}	290 ± 3.0^{c}	0.5 ± 0.2^{c}	4.5 ± 0.1^{d}	4050 ± 1.0^{e}
40m	42.0 ± 1.0^{b}	4.0 ± 0.3^{a}	129.0 ± 3.0^{e}	4.0 ± 0.1^{a}	31.0 ± 0.5^{a}	5550 ± 1.0^{d}
Control	1.5 ± 0.2^{a}	0.5 ± 0.1^{a}	121.5 ± 0.5^{b}	0.5 ± 0.2^{a}	2.5 ± 0.1^{a}	2850 ± 2.0^{b}

Values with different superscripts along the same column are significantly different at $p< 0.05$

TABLE 5: Heavy metal concentration (mg/kg) of soil samples from Omu-Aran dumpsite

Distance	Pb	Cd	Zn	Ni	Cu	Fe
0m	15.5 ± 0.5^{a}	0.5 ± 0.1^{a}	250 ± 5.0^{a}	4.0 ± 0.1^{a}	8.5 ± 0.1^{a}	6250 ± 1.0^{d}
10m	6.5 ± 0.1^{c}	0.5 ± 0.1^{a}	205 ± 1.0^{c}	0.5 ± 0.1^{c}	6.5 ± 0.0^{c}	5700 ± 3.0^{e}
20m	5.5 ± 0.2^{d}	0.5 ± 0.1^{a}	245 ± 1.0^{b}	1.0 ± 0.1^{b}	7.5 ± 0.2^{b}	7850 ± 5.0^{b}
30m	5.0 ± 0.5^{d}	0.5 ± 0.1^{a}	195 ± 1.0^{d}	0.5 ± 0.2^{c}	5.5 ± 0.2^{d}	6650 ± 1.0^{c}
40m	8.0 ± 0.0^{b}	0.0 ± 0.0^{b}	134.8 ± 0.8^{e}	0.7 ± 0.3^{c}	6.5 ± 0.2^{c}	15100 ± 1.0^{a}
Control	1.5 ± 0.2^{a}	0.5 ± 0.1^{a}	121.5 ± 0.5^{b}	0.5 ± 0.2^{a}	2.5 ± 0.1^{a}	2850 ± 2.0^{b}

Values with different superscripts along the same column are significantly different at $p< 0.05$

TABLE 6: Heavy metal concentration (mg/kg) of soil samples from Offa dumpsite.

Distance	Pb	Cd	Zn	Ni	Cu	Fe
0m	7.5 ± 0.1^{d}	0.0 ± 0.0^{b}	300 ± 2.0^{c}	1.5 ± 0.1^{b}	6.0 ± 0.5^{d}	5250 ± 1.0^{d}
10m	15.0 ± 0.4^{b}	0.5 ± 0.1^{a}	435 ± 0.0^{a}	1.0 ± 0.1^{c}	81.0 ± 2.0^{a}	6600 ± 2.0^{c}
20m	27.0 ± 0.3^{a}	0.0 ± 0.0^{b}	325 ± 2.0^{b}	4.5 ± 0.1^{a}	20.5 ± 0.5^{b}	19650 ± 4.0^{a}
30m	8.5 ± 0.1^{c}	0.5 ± 0.2^{a}	65.0 ± 1.0^{d}	1.0 ± 0.3^{c}	10.0 ± 0.2^{c}	7550 ± 3.0^{b}
40m	0.0 ± 0.0^{e}	0.5 ± 0.2^{a}	65.0 ± 2.0^{d}	1.0 ± 0.3^{c}	1.5 ± 0.2^{e}	5100 ± 1.0^{e}
Control	0.5 ± 0.2^{b}	0.5 ± 0.1^{a}	195 ± 2.0^{a}	0.0 ± 0.0^{b}	2.5 ± 0.1^{a}	3550 ± 1.0^{a}

Values with different superscripts along the same column are significantly different at $p < 0.05$

TABLE 7: Heavy metal concentration (mg/kg) of soil samples from Odo-ore

Distance	Pb	Cd	Zn	Ni	Cu	Fe
0m	10.0 ± 0.5^{a}	0.0 ± 0.0^{b}	280.0 ± 10.0^{a}	1.5 ± 0.1^{a}	6.0 ± 0.5^{b}	3600 ± 2.0^{c}
10m	1.5 ± 0.1^{c}	0.5 ± 0.1^{a}	94 ± 0.5^{e}	0.0 ± 0.0^{d}	3.5 ± 0.1^{d}	3300 ± 3.0^{d}
20m	3.5 ± 0.2^{b}	0.5 ± 0.0^{a}	210 ± 2.0^{d}	0.5 ± 0.2^{c}	0.5 ± 0.1^{e}	2187 ± 2.0^{e}
30m	10.5 ± 0.5^{a}	0.5 ± 0.0^{a}	240 ± 1.0^{c}	0.0 ± 0.0^{d}	5.0 ± 0.5^{c}	4300 ± 5.0^{b}
40m	10.0 ± 0.5^{a}	0.5 ± 0.0^{a}	270 ± 2.0^{b}	1.0 ± 0.1^{b}	7.5 ± 0.1^{a}	5950 ± 2.0^{a}
Control	0.5 ± 0.2^{b}	0.5 ± 0.1^{a}	195 ± 2.0^{a}	0.0 ± 0.0^{b}	2.5 ± 0.1^{a}	3550 ± 1.0^{a}

Values with different superscripts along the same column are significantly different at $p < 0.05$

TABLE 8: Heavy metal concentration (mg/kg) of soil samples from Aran-orin dumpsite

Distance	Pb	Cd	Zn	Ni	Cu	Fe
0m	3.0 ± 0.1^{d}	0.0 ± 0.0^{b}	260 ± 1.0^{d}	6.0 ± 0.1^{a}	5.0 ± 0.3^{d}	2950 ± 1.0^{d}
10m	5.5 ± 0.1^{b}	0.5 ± 0.5^{a}	450 ± 0.4^{b}	1.5 ± 0.1^{c}	14.33 ± 0.8^{a}	5700 ± 1.0^{c}
20m	4.0 ± 0.2^{c}	0.5 ± 0.2^{a}	220 ± 1.0^{e}	1.5 ± 0.2^{c}	6.0 ± 0.2^{c}	7330 ± 2.0^{b}
30m	8.4 ± 0.1^{a}	0.5 ± 0.1^{a}	480 ± 2.0^{a}	2.0 ± 0.2^{b}	7.5 ± 0.2^{b}	1390 ± 1.0^{e}
40m	8.0 ± 0.1^{a}	0.5 ± 0.1^{a}	445 ± 1.0^{c}	0.0 ± 0.0^{d}	6.0 ± 0.1^{c}	20850 ± 3.0^{a}
Control	0.5 ± 0.2^{b}	0.5 ± 0.1^{a}	195 ± 2.0^{a}	0.0 ± 0.0^{b}	2.5 ± 0.1^{a}	3550 ± 1.0^{a}

Values with different superscripts along the same column are significantly different at $p < 0.05$

TABLE 9: Heavy metal concentration (mg/kg) of soil samples from Ipee dumpsite.

Distance	Pb	Cd	Zn	Ni	Cu	Fe
0m	15.5 ± 0.5^{c}	0.5 ± 0.2^{b}	270 ± 2.0^{c}	1.0 ± 0.2^{b}	41.0 ± 0.5^{a}	6450 ± 5.0^{b}
10m	30.0 ± 0.5^{a}	0.5 ± 0.2^{b}	116 ± 1.0^{d}	0.0 ± 0.0^{c}	4.5 ± 0.1^{d}	4200 ± 1.0^{d}
20m	0.0 ± 0.0^{e}	0.5 ± 0.2^{b}	116 ± 1.0^{d}	0.0 ± 0.0^{c}	4.5 ± 0.4^{d}	3250 ± 1.0^{e}
30m	0.5 ± 0.1^{d}	0.0 ± 0.0^{c}	450 ± 0.4^{b}	1.0 ± 0.1^{b}	6.0 ± 0.2^{c}	6600 ± 1.0^{a}
40m	26.0 ± 0.5^{b}	4.0 ± 0.2^{a}	475 ± 2.0^{a}	19.5 ± 0.6^{a}	16.0 ± 0.2^{b}	4850 ± 5.0^{c}
Control	0.5 ± 0.2^{b}	0.5 ± 0.1^{a}	195 ± 2.0^{a}	0.0 ± 0.0^{b}	2.5 ± 0.1^{a}	3550 ± 1.0^{a}

Values with different superscripts along the same column are significantly different at $p < 0.05$

TABLE 10: Heavy metal concentration (mg/kg) of plant samples from Oko-Olowo dumpsite.

Distances	Plants encountered and analysed	Pb	Cd	Zn	Ni	Cu	Fe
0m	*Zea mays*	7.0 ± 1.0^{a}	0.5 ± 0.1^{a}	129.0 ± 2.0^{b}	3.5 ± 0.1^{a}	7.5 ± 0.2^{c}	3700 ± 1.0^{a}
10m	*Synedrella nodiflora.*	4.0 ± 0.2^{b}	0.4 ± 0.36^{a}	88 ± 2.0^{d}	1.0 ± 0.1^{b}	6.5 ± 0.2^{d}	2750 ± 5.0^{b}
20m	*Ageratum conyzoides*	6.5 ± 0.1^{a}	0.5 ± 0.0^{a}	132 ± 0.2^{a}	0.0 ± 0.0^{d}	15.0 ± 0.5^{a}	2250 ± 2.0^{d}
30m	*Ageratum conyzoides*	1.0 ± 0.4^{d}	0.5 ± 0.0^{a}	65.5 ± 0.8^{e}	0.5 ± 0.1^{c}	9.5 ± 0.6^{b}	2200 ± 10.0^{e}
40m	*Euphorbia heterophylla*	2.5 ± 0.3^{c}	0.5 ± 0.0^{a}	98.5 ± 0.5^{c}	0.5 ± 0.2^{c}	3.5 ± 0.3^{e}	2400 ± 40.0^{c}
Control	*Cyperus esculentum*	0.0 ± 0.0^{b}	0.0 ± 0.0^{b}	47.5 ± 1.32^{a}	0.03 ± 0.57^{a}	3.0 ± 0.5^{a}	250 ± 2.1^{b}

Values with different superscripts along the same column are significantly different at $p < 0.05$

TABLE 11: Heavy metal concentration (mg/kg) of plant samples from Omu-Aran dumpsite

Distance	Plants encountered and analysed	Pb	Cd	Zn	Ni	Cu	Fe
0m	*Mangifera indica*	1.0 ± 0.1^{c}	0.5 ± 0.3^{a}	121.0 ± 0.5^{a}	0.0 ± 0.0^{a}	2.0 ± 0.1^{bc}	2850 ± 1.0^{a}
10m	*Cyperus rotundus*	1.5 ± 0.2^{b}	0.5 ± 0.0^{a}	62.0 ± 1.0^{b}	0.0 ± 0.0^{a}	4.5 ± 0.2^{a}	2250 ± 0.0^{b}
20m	*Perostis indica*	0.0 ± 0.0^{d}	0.3 ± 0.2^{a}	16.0 ± 1.0^{e}	0.0 ± 0.0^{a}	1.5 ± 0.1^{c}	260 ± 5.0^{e}
30m	*Brachlaria deflesa*	2.0 ± 0.2^{a}	0.0 ± 0.0^{a}	34.0 ± 0.4^{c}	0.5 ± 0.2^{a}	3.5 ± 0.1^{ab}	700 ± 6.0^{c}
40m	*Digitaria nuda*	0.0 ± 0.0^{d}	0.5 ± 0.0^{a}	26.0 ± 0.6^{d}	1.5 ± 0.1^{a}	1.5 ± 0.1^{c}	585 ± 3.0^{d}

Values with different superscripts along the same column are significantly different at $p < 0.05$

TABLE 12: Heavy metal concentration (mg/kg) of plant samples from Offa dumpsite

Distance	Plants encountered and analysed	Pb	Cd	Zn	Ni	Cu	Fe
0m	*Commelina diffusa*	4.5 ± 0.2^{a}	0.5 ± 0.2^{a}	66.0 ± 0.3^{c}	0.5 ± 0.2^{b}	6.0 ± 0.1^{b}	3750 ± 5.0^{b}
10m	*Schwenckia americana*	0.0 ± 0.0^{c}	0.5 ± 0.2^{a}	82.5 ± 0.5^{b}	0.5 ± 0.2^{b}	3.5 ± 0.2^{c}	520 ± 1.0^{d}
20m	*Aspilia africana*	0.0 ± 0.0^{c}	0.0 ± 0.0^{b}	30.5 ± 0.5^{e}	1.0 ± 0.1^{a}	3.0 ± 0.1^{d}	460 ± 5.0^{e}
30m	*Talinum triangulare*	2.0 ± 0.1^{b}	0.0 ± 0.0^{b}	310 ± 5.0^{a}	1.0 ± 0.1^{a}	8.0 ± 0.4^{a}	4950 ± 5.0^{a}
40m	*Eragrostis tenella*	0.0 ± 0.0^{c}	0.5 ± 0.1^{a}	60.5 ± 0.5^{d}	0.0 ± 0.0^{c}	2.5 ± 0.1^{e}	530 ± 3.0^{c}
Control	*Sida acuta*	2.5 ± 0.2^{a}	2.2 ± 0.2^{a}	28.5 ± 0.5^{b}	0.0 ± 0.0^{a}	1.0 ± 0.0^{b}	320 ± 2.0^{a}

Values with different superscripts along the same column are significantly different at $p < 0.05$

TABLE 13: Heavy metal concentration (mg/kg) of plant samples from Odo-Ore dumpsite

Distances	Plants encountered and analysed	Pb	Cd	Zn	Ni	Cu	Fe
0m	*Amaranthus spinosus*	0.5 ± 0.1^{d}	0.5 ± 0.2^{a}	70.0 ± 2.0^{b}	0.7 ± 0.3^{c}	5.5 ± 0.1^{a}	3000 ± 1.0^{d}
10m	*Sida acuta*	0.0 ± 0.0^{e}	0.5 ± 0.1^{a}	59.5 ± 0.5^{c}	5.0 ± 0.2^{a}	1.5 ± 0.2^{e}	3250 ± 1.0^{c}
20m	*Amaranthus spinosus*	4.5 ± 0.2^{b}	0.5 ± 0.1^{a}	130 ± 0.6^{a}	1.5 ± 0.2^{b}	3.0 ± 0.3^{c}	2700 ± 2.0^{e}
30m	*Cynodon dactylon*	6.9 ± 0.46^{a}	0.5 ± 0.1^{a}	61.5 ± 1.0^{c}	0.5 ± 0.2^{c}	3.5 ± 0.3^{b}	3950 ± 5.0^{a}
40m	*Cyperus esculentus*	1.5 ± 0.2^{c}	0.5 ± 0.2^{a}	68.0 ± 1.0^{b}	0.0 ± 0.0^{d}	2.0 ± 0.3^{d}	3700 ± 3.0^{b}

Values with different superscripts along the same column are significantly different at $p < 0.05$

TABLE 14: Heavy metal concentration (mg/kg) of plant samples from Aran-Orin.

DISTANCES	Plants encountered and analysed	Pb	Cd	Zn	Ni	Cu	Fe
0m	*Tithonia diversifolia*	0.0 ± 0.0^{a}	0.5 ± 0.1^{a}	31.0 ± 0.5^{b}	5.5 ± 0.2^{a}	1.0 ± 0.1^{c}	770 ± 5.0^{a}
10m	*Sida acuta*	0.0 ± 0.0^{a}	0.5 ± 0.1^{a}	41.0 ± 2.0^{a}	0.0 ± 0.0^{d}	5.0 ± 0.1^{a}	215 ± 2.0^{d}
20m	*Sida acuta*	0.0 ± 0.0^{a}	0.5 ± 0.2^{a}	41.0 ± 2.0^{a}	0.0 ± 0.0^{d}	5.0 ± 0.1^{a}	215 ± 2.0^{d}
30m	*Sida acuta*	0.0 ± 0.0^{a}	0.5 ± 0.2^{a}	27.5 ± 1.32^{c}	1.5 ± 0.1^{b}	0.0 ± 0.0^{d}	425 ± 5.0^{c}
40m	*Synedrella nodiflora*	0.0 ± 0.0^{a}	0.5 ± 0.2^{a}	40.93 ± 1.10^{a}	0.5 ± 0.1^{c}	2.6667 ± 0.35119^{b}	570 ± 1.0^{b}

Values with different superscripts along the same column are significantly different at $p < 0.05$

TABLE 15: Heavy metal concentration (mg/kg) of plant samples from Ipee.

Distances	Plants encountered and analysed	Pb	Cd	Zn	Ni	Cu	Fe
0m	*Sida rhombifolia*	0.0 ± 0.0^{c}	0.0 ± 0.0^{b}	33.5 ± 0.5^{b}	0.0 ± 0.0^{b}	3.5 ± 0.1^{a}	4300 ± 3.0^{a}
10m	*Synedrella nodiflora*	0.0 ± 0.0^{c}	0.0 ± 0.0^{b}	38.0 ± 2.0^{a}	0.5 ± 0.1^{a}	1.0 ± 0.0^{d}	695 ± 1.0^{b}
20m	*Sida rhombiflora*	1.0 ± 0.1^{b}	0.0 ± 0.0^{b}	21.0 ± 0.3^{c}	0.5 ± 0.2^{a}	1.5 ± 0.1^{c}	320 ± 1.0^{c}
30m	*Cassia fistula*	0.0 ± 0.0^{c}	0.5 ± 0.2^{a}	19.5 ± 0.5^{c}	0.5 ± 0.2^{a}	2.0 ± 0.3^{b}	195 ± 1.0^{e}
40m	*Aspilia africana*	2.0 ± 0.2^{a}	0.5 ± 0.2^{a}	20.0 ± 0.2^{c}	0.5 ± 0.2^{a}	2.0 ± 0.3^{b}	240 ± 2.0^{d}

Values with different superscripts along the same column are significantly different at $p < 0.05$

The concentrations of heavy metals present in plant samples collected from Oko – Olowo dumpsite are shown in Table 10. The sequence of heavy metal concentrations in plant samples is as follows: Fe > Zn > Cu > Pb > Ni > Cd

From the trend, Fe has the highest concentration in the location followed by Zn while Cd had the lowest concentration. It was further observed that the concentrations of the heavy metals present in the plant samples were less than those of the soil samples from Oko-Olowo dumpsite (Table 4).The concentrations of heavy metals present in plant samples collected from Omu-Aran dumpsite are presented in Table 11. The sequence of heavy metal concentrations in plant samples is as follows: Fe > Zn > Cu > Pb > Ni > Cd

The trend showed that Fe has the highest concentration in the plant samples collected from the dumpsite followed by Zn while the least was Cd. It was further observed that the concentrations of heavy metals present in the plant samples were less than those of the soil samples from Omu-Aran dumpsite (Table 5). The concentrations of the heavy metals found in these plant samples were higher than those of the plant collected from the Control sites.

The concentrations of heavy metals present in plant samples collected from the dumpsite in Offa are shown in Table 12. The sequence of the heavy metal concentrations is thus:

Fe > Zn > Cu > Pb > Ni > Cd

The trend showed that Fe had the highest concentration in the plant samples followed by Zn while the least was Cadmium. It was observed that the concentrations of heavy metals present in the plant samples were far less than those of the soil samples (Table 12). The concentrations of the metals found in these plant samples were found to be higher than the Control (Table 12) with

the exception of Zn that was lower at 20m than plants collected from Ile-Oba in Offa which served as the Control (Table 12).

Table 13 shows the concentrations of heavy metals found in plant samples collected from the dumpsites at Odo-Ore. The sequence of the heavy metal concentration is thus:

Fe > Zn > Cu > Pb > Ni > Cd

From the trend, Fe had the highest concentration in the plant samples followed by Zn while the least was Cd. It was observed that the concentration of heavy metals present in the plant samples were less than those of the soil samples except for Fe that fell within the same range with both the plant and soil samples. The concentrations of the heavy metals found in these plant samples were found to be higher than the Control.

The concentrations of the heavy metals present in the plant samples collected from the dumpsite in Aran-Orin are shown in Table 14. The sequence of the heavy metal concentrations is thus:

Fe > Zn > Cu > Ni > Cd > Pb

The trend showed that Fe had the highest concentration in the plant samples followed by Zn while the least was lead. This is unlike the other dumpsites where plant samples were taken such as Oko-olowo, Omu-Aran, Offa and Odo-ore where Cd had the least concentration. It was observed that the concentrations of heavy metals present in the plant samples were far less than those of the soil samples. (Table 8). It was observed that the concentrations of all the heavy metals at 10 and 20metres were the same. The concentrations of heavy metals found in these plant samples were found to be higher than the concentration of plant samples from the Control sites.

The concentration of heavy metals present in plant samples collected from the dumpsites in Ipee are shown in Table 15. The sequence of the heavy metal concentration is thus:

Fe > Zn > Cu > Pb > Ni > Cd

From the trend, Fe has the highest concentration of 4300mg/kg in the plant samples collected at the core of the dumpsite followed by Zn (38mg/kg) while Cd had the lowest concentration of 0.0mg/kg (Table 15). It was observed that the concentrations of the heavy metals present in the plant samples were generally less than those of the soil samples (Table 9) with the exception of Fe contents in plants collected from 0m that is, the core of the dumpsite that fell within the range of the heavy metal content in the soil. Heavy metal contents found in plants collected from the dumpsite were found to be higher than the contents in plants collected from the Control sites for some of the heavy metals with the exception of Zn that was higher in the plants from the Control sites than plants from the dumpsites (Table 15).

It was generally observed that the concentrations of Iron was the highest in all the plant samples collected from various dumpsites and analysed while Cd was the least in all the various dumpsite except at Aran-Orin dumpsite where Pb had the lowest concentration (0.0 mg/kg). Moreover, the heavy metal concentrations at the urban dumpsites were found to be higher than those in the rural dumpsites. When the heavy metal concentrations of soil samples were statistically tested, it was found that there were significant differences among all the soil samples collected from 0m Urban (Appendix 1) of all dumpsites at $p<0.05$ (Appendix 1). All soil samples at 10m of all the urban dumpsites showed significant differences at $p<0.05$ (Appendix 1). ANOVA showed that all the soil samples collected at 20m urban, 30m urban and 40m urban were statistically different at $p\leq0.05$ (Appendix 1).

The statistical analyses of all the soil samples collected from the urban dumpsites at each location are presented in Appendix 1a. It was found that the heavy metal content of soil samples at 0m Urban differed significantly at $p<0.05$. The mean values where subjected to DMRT, it was found that all the heavy metals were not statistically the same such that Fe was significantly greater than Zn, Zn was statistically greater than Pb, Pb was statistically greater than Cu, which was in turn statistically greater than Ni and Ni was statistically greater than Cd (Appendix 1a) at $p<0.05$. ANOVA the heavy metal contents of soil samples at 10m urban, 20m urban, 30m urban and 40m urban of all the three dumpsites showed statistical differences at $p<0.05$ (Appendix 1b, c, d and e). Separation of the mean values of the heavy metals at 10m urban revealed that Ni and Cd were statistically the same but Fe was statistically greater than Zn, Cu, Pb, Cd and Ni (Appendix 1b).

At 20m urban, separation of the heavy metal concentrations revealed that Cd, Ni, Cu, Pb, Zn and Fe were significantly different such that Fe was found to be statistically greater than Zn, Pb, Cu, Ni and Cd at $p<0.05$ (Appendix 1c). Appendix 1d shows that the separation of the heavy metal concentrations of soil at 30m urban of all dumpsites into different statistical groups. Cd and Ni formed a group without any significant difference while the other heavy metals were separated such that Fe was statistically greater than Zn, Cu, Pb, Ni, and Cd at $p<0.05$. This is the same trend with Appendix 1c. The heavy metal concentrations of soil at 40m urban when separated gave same result like those of soil samples in 0m and 20m (Appendix 1a and 1c) (Appendix 1e).

The statistical comparison of all soil samples at the rural dumpsites showed that all the soil samples per location were statistically different at $p<0.05$ (Appendix II). Separation of the heavy metal contents of soil at 0m rural dumpsites showed that Cd, Ni, Pb, Cu, Zn and Fe were

statistically different and that Fe was significantly greater than Zn, Cu, Pb, Ni and Cd (Appendix II a). At 10m rural, separation of the heavy metal concentrations showed that Ni, Cu, Pb and Cd formed a group without any significant difference while Fe was statistically greater than Zn, Cd, Pb, Cu and Ni at $p<0.05$ (Appendix 11b) Fe > Zn > Ni= Cu = Pb = Cd.

Appendix IIc shows the separation of the heavy metal concentration of soil at 20m rural dumpsites into different statistical groups. Cd and Ni formed a group without any significant difference, Pb and Cu formed another group without any significant difference while there were significant differences between Fe and Zn as Fe was statistically greater than Zn, Cu, Pb, Ni and Cd and $p<0.05$. The same trend was observed for 30m rural (Appendix II d) Fe > Zn > Pb = Cu > Cd> Ni.

The heavy metal concentrations of soil at 40m rural dumpsite, when separated gave same result like those of soil samples at 0 m rural. When the soil samples from the Control were compared statistically with ANOVA, it was found that there were significant differences at $p<0.05$ (Appendix III). Further statistical analysis of the soil samples of the Control with DMRT showed that Ni, Cd, Pb, Cu and Zn were statistically the same but Fe was statistically greater than Ni, Cd, Pb, Cu and Zn (Appendix IIIa) Fe> Zn = Cu = Pb = Ni = Cd. When the concentrations were compared with the dumpsite soils, it was found that all the heavy metals in the dumpsite soil were more than the corresponding metals in the control suggesting that the dumps had affected the soil by making them to contain more heavy metals that is the dump materials have added more heavy metals to the soils.

The separation of means of the heavy metals of the plant samples under study showed that these metals contributed differently to the pollution status of the plants. Plants at 0 m Urban of all dumpsites have their Cd and Ni statistically the same, and Pb and Cu statistically the same

while Zn and Fe were statistically different but the latter significantly more than the former (Fe > Zn > Pb = Cu > Cd = Ni) (Appendix IV a). Appendix IVb shows the separation of the heavy metal concentrations of plants at 10 m Urban from all dumpsites. Cd, Ni and Pb were statistically the same while there were significant differences among Cu, Zn and Fe but Fe was significantly greater than Zn, Cu, Pb, Ni and Cd at $p<0.05$ Fe > Zn > Cu > Pb = Ni = Cd. The observations and results for 10 m Urban were the same for 20 m Urban and 30 m Urban plants (Appendix IV c and IV d). For heavy metal contents of plants at 40 m Urban dumpsites, Cd, Ni, Pb and Cu were statistically the same but significantly different from Zn and Fe while Fe was statistically greater than Zn, Cu, Pb, Ni and Cu at $p<0.05$ (Appendix IV e).

The analysis of all plants at the rural dumpsites showed that all the plant samples per location were statistically different at $p<0.05$ (Appendix V). Separation of the heavy metal contents of plants at 0 m Rural have Pb and Cd statistically the same, Ni and Cu were statistically the same while Fe and Zn were statistically different but Fe was statistically greater than Zn, Cu, Ni, Cd and Pb at $p<0.05$ (Appendix V a) Fe > Zn > Ni = Cu > Pb = Cd. The same trend was observed for plants at 10m rural (Appendix V b). Appendix Vc shows the separation of the heavy metal concentrations of plants at 20m rural dumpsites. Cd and Ni were statistically the same while there were significant difference between Pb, Cu, Zn and Fe but Fe was statistically greater than Zn, Cu and Pb at $p<0.05$. Fe > Zn > Cu = Pb > Cd = Ni. For heavy metal contents of plants at 30 m rural dumpsites, Cd, Ni, Cu and Pb were statistically the same but significantly different from Zn and Fe which were statistically different but Fe was greater than Zn at $p<0.05$ (Appendix V d).

Appendix V e shows the separation of heavy metal content of plants at 40 m Rural. There were no significant differences among Ni, Cd and Pb but statistically lower than Pb and Cu which

were statistically the same while there was significant difference between Zn and Fe but Fe was statistically greater than Zn which in turn was greater than Cu, Pb, Cd and Ni (Appendix V e). The Zn and Fe contents of the plant materials of these locations were the same but Fe was greater than Zn, Cu, Pb, Cd and Ni at $p<0.05$ (Appendix V a, b, c, d and e).

When the plant samples Control were compared statistically with ANOVA, it was found that there were significant differences at $p<0.05$ (Appendix VI). Further analysis of the plant samples from the Control with DMRT showed that Ni, Cd, Pb, Cu and Zn were statistically the same but Fe was statistically greater than Zn, Cu, Pb, Cd and Ni at $p<0.05$ (Appendix VI a). When the heavy metal concentrations of the plants from the Control were compared with those from the dumpsites, it was found that all the heavy metals in the plants from the dumpsites were more than the corresponding metals in the plants from the Control, suggesting that the dumps have contributed to affected the pollution status of the plants and the soil.

Furthermore, the concentration of heavy metals found in the soil samples from the control site were higher than those obtained from the plants collected from these control sites. With the exception of Cu and Pb that were higher in the plants than the soil.

The correlation coefficient between the concentrations of heavy metals in the soil and plant collected from Oko-Olowo, Omu-Aran, Offa, Odo-Ore, Aran-Orin and Ipee dumpsite were repeated in Appendix VII. The heavy metal in soil at 0, 10, 20, 30 and 40 meters of all these dumpsites correlated positively with the heavy metal in the plants at all the distances at $p<0.05$. The strong correlation between heavy metals in soil and plants signified that they have the same source of pollution which support that the heavy metals were in the plant is from

TABLE 17 FAO/ WHO GUIDELINES FOR METALS IN FOOD AND VEGETABLES

Metals	WHO/FAO	NAFDAC	EC/CODEX	Normal range in plants (mg/kg)
Cd	1	NM	0.2	< 2.4
Cu	30	20	0.3	2.5
Pb	2	2	0.3	0.50 – 3.0
Zn	60	50	<50	20 – 100
Fe	48	NM	NM	400 - 500
Ni	NM	NM	NM	0.02 – 50

The level of Pb in plant samples from Oko-Olowo were above the level recommended by WHO/FAO for metals in food and vegetables (2.0mg/kg) and were also within the normal range of the metal in plants (0.50-3.0 mg/kg) with the exception of plants collected at 30 m and 40 m away from the core of the dumpsite that has 1.0mg/kg and 2.5mg/kg respectively. Therefore the consumption of the vegetables/plants on this site may be considered unsafe for human consumption. The level of Pb in Omu aran and Offa were below the level recommended by

WHO/FAO for metals in food and vegetables (2.0mg/kg) and are also within the normal range of the metal in plants (0.50-3.0 mg/kg) with the exception of plants collected from Offa at 0 m away from the core of the dumpsite that has 4.5 mg/kg. Therefore the consumption of the vegetables/plants on this site may be considered safe but the accumulation maybe dangerous (Table 17). Pb concentration in Odo-Ore, Aran-Orin and Ipee were below the level recommended by WHO/FAO for the metal in food and vegetables (2.0mg/kg) and are also within the normal range of metals in plants (0.50-3.0 mg/kg) with the exception of plants collected from Odo-Ore at 20 m and 30 m away from the core of the dumpsite that has 4.5 mg/kg and 6.9 mg/kg respectively. Therefore the consumption of the vegetables/plants on this sites may be considered safe with the exception of Odo-Ore but the accumulation maybe dangerous (Table 17)

Cd concentrations in plant samples from 0m, 10m, 20m, 30m, 40m of all dumpsites and Control were below the levels recommended by WHO/FAO for metals in food and vegetables (1.0mg/kg) and were also within the normal range of the metal in plants (<2.4mg/kg).

Zn concentration in plant samples from 0 m of all dumpsites fell within the normal range of the metal in plants (20-100 mg/kg) with the exception of Oko-Olowo and Omu-Aran dumpsites which had 129mg/kg and 121mg/kg concentration for Zn, respectively that were higher than the normal range in plants. Zn concentration in plant samples from 10m of all dumpsites were below the recommended level by WHO/FAO for metals in food and vegetables (60mg/kg) with the exception of Oko-Olowo, Omu-Aran and Offa which had Zn concentration in the plants collected from them as 88.0mg/kg, 62.0mg/kg and 82.5mg/kg respectively which were above the levels recommended by WHO/FAO but all the dumpsites fell within the normal range of the metal in plants (20-100mg/kg). Moreover, Zn concentration in plant samples from 20m of all the

dumpsites were below the level recommended by WHO/FAO for metals in food and vegetables and also fell within the normal range of metals in plants with the exception of plants collected from Oko-Olowo and Odo-Ore which had 132.0mg/kg and 130.5mg/kg, respectively. Moreover, Zn concentration in plant samples collected from 30m of all dumpsites were below the levels recommended by WHO/FAO for metals in food and vegetables with the exception of plants collected from Oko-Olowo, Offa and Odo-Ore which had 65.0mg/kg, 310mg/kg, 61.5mg/kg respectively which were higher than the WHO/FAO limits (60mg/kg). Plants collected from all the dumpsites fell within the normal range of metals in plants (20-100mg/kg) except plants collected from Offa dumpsite which had 310mg/kg which was extremely higher than the normal range. Furthermore, Zn concentration in plant samples collected from 40m of all dumpsites were below the levels recommended by WHO/FAO for metals in food and vegetables with the exception of Oko-Olowo and Odo-Ore which had 98.5mg/kg and 68.0mg/kg, respectively. They were higher than the levels recommended by WHO/FAO but all the plants collected at 40m of all the dumpsites fell within the normal range of metals in plants (Table 17). Those sites with higher heavy metals than WHO/FAO limits are prone to hazardous effects of the heavy metals in question.

Zn concentrations from the control sites were below the levels recommended by WHO/FAO for metals in food and vegetables and are also within the normal range of metals in plants. This shows that the plants are safe for consumption.

Ni concentration in plant samples collected from 0m, 10m, 20m, 30m, 40m of all the dumpsites and Control were within the normal range of metals in plants (0.02-50mg/kg).

Cu concentration in plant samples collected from 0m of all the dumpsites were below the level recommended by WHO/FAO for metals in food and vegetables (30mg/kg) but plants from Oko-

Olowo, Offa, Odo-Ore and Ipee had 7.5mg/kg, 6.0mg/kg, 5.5mg/kg and 3.5mg/kg respectively. They had more Cu concentration than the normal range in plants (2.5mg/kg) while plants from Omu-Aran and Aran-Orin falls within the normal range of Cu contents in plants. Cu concentration in plant samples collected from 10m of all the dumpsites were below the levels recommended by WHO/FAO for metals in food and vegetables but plants collected from Oko-Olowo, Omu-Aran, Offa and Aran-Orin had 6.5mg/kg, 4.5mg/kg, 3.5mg/kg and 5.0mg/kg, respectively which were more than the normal recommended range in plants while plants collected from Odo-Ore and Ipee fell within the range.

Cu concentration in plant samples collected from 20m of all dumpsites were below the level recommended by WHO/FAO for the metal in food and vegetables but plants from Oko-Olowo, Offa, Aran-Orin and Odo-Ore had more Cu concentration than the recommended normal range of metals in plants while Plants collected from Omu-Aran and Ipee fell within the range. At 30m, Cu concentration in plants collected from Aran-Orin and Ipee fell within the range recommended by WHO/FAO for the Cu in food and vegetables and are also within the normal range of metals in plants. At 40m, Cu concentration in plants collected from Oko-Olowo and Aran-Orin exceeded the limits recommended by WHO/FAO for metals in food and vegetables but were within the normal range of Cu in plants. Plants collected from the Control site in Oko-Olowo exceeded the recommended limit for Cu concentration by WHO/FAO for metals in food and vegetables while Cu was absent in the Control from Offa (Table 17).

Fe concentration in plant samples collected from 0m of all the dumpsites exceeded the normal range recommended by WHO/FAO for Fe in food and vegetables. Fe concentration in plant samples from 10m of all the dumpsites exceeded the normal range recommended by WHO/FAO for Fe in food and vegetables with the exception of plants collected from Aran-Orin which fell

within the range. Moreover, Fe concentration in plant samples collected from 20m of all the dumpsites falls within the range recommended by WHO/FAO for the metal in food and vegetables and were also within the normal range of metals in plants with the exception of plants collected from Oko-Olowo and Odo-Ore that exceeded the normal range recommended for Fe contents in plants by WHO/FAO. Furthermore, Fe concentration in plant samples collected from 30m of all the dumpsites exceeded the normal range recommended by WHO/FAO for Fe in food and vegetables with the exception of plants collected from Aran-Orin and Ipee that fell within the recommended range. All plants collected from 40m of all the dumpsites exceeded the normal range recommended for Fe contents in plant by WHO/FAO for the metal in food and vegetables except plants collected from Ipee that fell within the recommended range (Table 17). Plant samples collected from all the control sites were below the recommended range by WHO/FAO for Fe in food and vegetables. Hence, the plants from the Control sites were not polluted with Fe.

Table 18 Standard value for Agricultural soil

Heavy metals	World Health Organization (mg/kg)	European Union Standard (mg/kg)
Cd	0.01-3.0[2]	3.0
Cu	NA	140
Pb	90-400[1]	300
Zn	NA	300
Fe	NA	NA
Ni	35[3]	75

[1]WHO (1993); NEPCA (2010)

[2]MAFF (1992); EC (1986)

[3]WHO (1996)

The level of Pb concentration in soil samples from 0m, 10m, 20m, 30m, 40m of all the dumpsite locations and the Control were lower than EU upper limit of 300mg/kg (EU, 2002) and were at lower concentration than the maximum tolerable levels proposed for agricultural soil (90-400mg/kg) (NEPCA, 2010; WHO 1993)

Cd concentrations in the soil samples from all the dumpsites and Control locations fell within the range of the EU upper limits of 0.01-3.0mg/kg (MAFF, 2002) and were lower than the maximum tolerable levels proposed for agricultural soil (3.0mg/kg) (EU, 2002) except for Cd in Ipee

dumpsite at 40meters away from the centre of the dumpsite which had 4.0mg/kg, that is, higher than the EU upper limit (EU, 2002; MAFF, 2002).

Zn concentrations in soil samples from 0m of all dumpsites fell below the EU upper limit of 300mg/kg (EU, 2002). At 10m, Zn concentrations in all the dumpsites fell below the EU limit except Oko-Olowo and Offa that had 1205mg/kg and 435mg/kg, respectively which is above the EU upper limit of 300mg/kg. At 20m, Zn concentrations in all the dumpsites were below the EU upper limit except at Oko-Olowo and Offa that had 410mg/kg and 325mg/kg respectively which were above the EU upper limit for agricultural soil. At 30m, Zn concentration in soil samples from all the dumpsites were below the EU upper limit with the exception of Aran-Orin that had 480mg/kg which was above the EU upper limit for proposed agricultural soil. At 40m, Zn concentrations in soil from all the dumpsites were below the EU upper limit with the exception of Oko-Olowo, Aran-Orin and Ipee that had 1290mg/kg, 445mg/kg and 475mg/kg, respectively which were above the EU upper limit for agricultural soil. The Zn concentrations in the soil from the Control sites were below the EU upper limit of 300mg/kg.

Ni concentrations in soil samples from all the dumpsites and Control sites of locations were far below the EU upper limit for Ni (75mg/kg) (EU,2002), and WHO maximum tolerable levels proposed for agricultural soil (35mg/kg) (WHO, 1996).

Cu concentrations in soil samples from the Control and all the dumpsite locations were lower than the EU upper limit for Cu which is 140mg/kg (EU, 2002) except for Oko-Olowo dumpsite location at 10m that had a higher level of Cu than the EU upper limit.

The degree of pollution of the refuse dumpsites by the heavy metals were assessed (Table 19) using the Geo-Accumulation Index (I_{geo}) Classification by Forstner *et al.*,(1993) and Oyekunle *et*

al.,(2011). The calculated Geo-Accumulation Index results showed that all the dumpsites ranged from Unpolluted to Moderately polluted with Zn, Ni, Cu and Fe while Pb in all the dumpsites were moderately polluted to strongly polluted by Pb. Furthermore, the dumpsites were not polluted with Cd except at Ipee. The classification showed that the refuse-demped soil from Omu-Aran was the least polluted with the heavy metals.

Table 19. GEO-ACCUMULATION INDEX AND CLASSIFICATION OF DUMPSITES

Location/ Heavy Metals	Pb	Cd	Zn	Ni	Cu	Fe
Oko-Olowo	2.61 (MP-SP)	0.69 (UP)	0.90 (UP-MP)	0.80 (UP-MP)	0.99 (UP- MP)	0.57 (UP-MP)
Omu-Aran	1.28 (MP)	0.62 (UP)	0.12 (UP-MP)	0.57 (UP-MP)	0.61 (UP-MP)	0.66 (UP-MP)
Offa	2.96 (MP-SP)	0.40 (UP)	0.27 (UP-MP)	0.59 (UP-MP)	1.85 (MP)	0.56 (UP-MP)
Odo-Ore	2.25 (MP-SP)	0.40 (UP)	0.18 (UP-MP)	0.0 (UP)	0.18 (UP-MP)	0.10 (UP)
Aran-Orin	2.04 (MP-SP)	0.41 (UP)	0.71 (UP-MP)	1.09 (MP)	0.73 (UP-MP)	0.58 (UP-MP)
Ipee	3.18 (SP)	0.61 (UP-MP)	0.45 (UP-MP)	1.97 (MP)	1.34 (MP)	0.17 (UP-MP)

UP- Unpolluted

MP- Moderately polluted SP- Strongly polluted

Characterization of Biochar, % germinatio

Table 20a shows the analysis of the growth parameters for Okra. At 2WAP, the Okra on the control soil had the highest shoot height (11.3cm) while the Okra on the Dumpsite soil had the lowest shoot height (8.83cm). when subjected to DMRT, it showed that the shoot height of Okra planted on dumpsite soils, Dumpsite with Biochar soil, Control soil and with Biochar Control soil were statistically the same at $p<0.05$ (Appendix 1a). The number of leaves in the Okra plant at 2WAP showed that the Okra on the control soil had the highest number of leaves (5) while the Okra on the Dumpsite soil had the lowest number of leaves (3.67). The mean of the number of leaves were subjected to DMRT which showed that the number of leaves on the Control soil was statistically greater than the number of leaves from the dumpsite soil, Dumpsite soil with Biochar and Biochar with Control soil which were statistically the same at $p<0.05$ (Appendix1b). the leaf lengths of the Okra plant on the dumpsite soil were statistically the same with the Control soil but were statistically greater than those from the Biochar with the Dumpsite soil and Biochar with the Control soil at $p<0.05$ (Appendix 1c).

The leaf length follows this trend: CS=DS>BC=BD

The leaf breadth of the Okra plant at 2WAP were significantly different for all the soil types at $p<0.05$. the leaf breadth were found to be higher in the Control soil than the Dumpsite soil which was statistically greater than Biochar with the Control soil which was also greater than Biochar with the Dumpsite soil at $p<0.05$ (Appendix 1d).

The leaf breadth follows this trend: CS > DS > BC > BD

The petiole length of the Okra plant at 2WAP in all the soil types showed that there were no

significant differences among them. That is, they were all statistically the same at $p<0.05$ (Appendix 1e).

The petiole length follows this trend: DS = BD = CS = BC

Table 20a shows the growth parameters of Okra plant at 4WAP. It was found that there were no significant differences among the shoot heights at $p<0.05$ (Appendix II a)

The highest number of leaves of the Okra plant at 4WAP were found in Biochar with Dumpsite soil (5cm) while the lowest shoot height was found in Biochar with Control soil (3cm). The mean values were subjected to DMRT which showed that the number of leaves in okra plant on Biochar with Dumpsite soil was statistically greater than the number of leaves in the Dumpsite soil and the Control soil which were statistically the same but statistically greater than the number of leaves from the Biochar with Control soil at $p<0.05$ (Appendix II b). The number of leaves of Okra at 4WAP follows this trend: BD > DS=CS >BC

Table 20a: Growth Performance of Okra in different Soil Treatments

2WAP	Shoot Height	Number of leaves	Leaf length	Leaf breadth	Leaf Area	Petiole length
DS	8.83±0.76[a]	3.67±0.56[b]	4.17±0.42[a]	3.8±0.28[b]	8.01±1.1[b]	2.23±0.25[a]
BD	9.30±0.96[a]	4.00±0.0[b]	3.20±0.10[b]	3.20±0.10[d]	5.12±0.2[c]	2.67±0.35[a]
CS	11.3±1.94[a]	5.00±0.00[a]	4.57±0.40[a]	4.53±0.15[a]	10.4±1.27[a]	2.5±0.00[a]
BC	9.77±1.15[a]	4.00±0.00[b]	3.30±0.10[b]	3.53±0.15[c]	5.83±0.39[c]	7.47±8.25[a]
4WAP						
DS	12.23±1.8[a]	4.00±0.00[b]	5.40±0.17[ab]	5.03±0.4[b][c]	13.6±1.5[a][b]	3.07±0.50[a]
BD	12.60±1.8[a]	5.00±0.00[a]	5.00±1.05[ab]	5.57±0.4[a][b]	13.9±3.7[a][b]	3.67±0.30[a]
CS	11.83±4.7[a]	4.0±1.0[b]	6.23±1.07[a]	6.23±0.92[a]	19.7±5.93[a]	3.50±0.45[a]
BC	12.17±1.7[a]	3.00±0.00[c]	4.27±0.35[b]	4.40±0.10[c]	9.38±0.68[b]	2.±0.00[b]
6WAP						
DS	18.5±2.8[a][b]	4.33±0.58[a]	5.93±0.80[a]	6.33±0.55[a]	18.9±3.93[a]	3.57±0.058[b]
BD	19.2±0.25[a]	4.67±0.58[a]	5.2±0.75[ab]	5.70±0.82[a]	15.06±4.1[a]	3.90±0.30[b]
CS	14.4±3.7[b][c]	5.0±1.00[a]	4.13±0.15[b]	5.50±0.50[a]	11.3±0.96[a]	5.07±0.25[a]
BC	13.5±1.50[c]	4.0±0.00[a]	5.4±0.86[ab]	6.20±1.10[a]	17.1±5.58[a]	2.8±0.21[c]

Values with different superscripts along the same column are significantly different at $p < 0.05$

WAP- Weeks after Planting

DS - Dumpsite Soil

BD – Biochar with Dumpsite soil

CS – Control Soil

BC – Biochar with Control soil

The highest leaf length of the Okra plant at 4WAP was found in the Control soil (6.2cm) while the lowest (4.2cm) was found in Biochar with the Control soil. The mean values were subjected to DMRT which when separated fell into two groups showing Biochar with Control soil, Biochar with Dumpsite soil and Dumpsite soil as a group of same value without any significant differences while the Control soil, Dumpsite soil and the Biochar with Dumpsite soil formed the other group of the same value but the Control soil was significantly greater than Dumpsite soil, Biochar with Dumpsite soil and Biochar with the Control soil at $p<0.05$ (Appendix II c). The leaf length of Okra plant at 4WAP follows this trend: CS> DS = BD > BC

It was found from Table 20a, that the highest leaf breadth of the Okra plant at 4WAP (6.2cm) was found on the Control soil while the lowest leaf breadth (4.4cm) was found on the Biochar with the Control soil. The leaf breadth in the Biochar with Dumpsite soil was statistically greater than Dumpsite Soil which was not statistically different from the leaf breadth in Biochar with the Control soil at $p<0.05$ (Appendix II d).

The leaf breadth of Okra at 4WAP follows this trend: CS > BD > DS > BC.

The same trend was followed by the leaf area at $p<0.05$ (Appendix II e).

The petiole length in the Okra plant at 4WAP has the highest length (3.6cm) on Biochar with Dumpsite soil while the lowest length (2.0cm) was found on Biochar with Control soil. When the means were subjected to DMRT, there were no significant differences among the petiole length in the Biochar with the dumpsite soil, Dumpsite soil and the Control soil but significantly different from the petiole length in the Okra plant on Biochar with the Control soil at $p<0.05$ (Appendix II f).

Table 20a also shows the growth parameters of Okra plant at 6WAP. The highest shoot height (19.2cm) was found in okra plant on Biochar with dumpsite soil while the lowest height (13.5cm) was found in Biochar with the control soil. The mean was subjected to DMRT, it was found that the shoot height in Dumpsite soil and Control soil was not significantly different from the shoot height in Biochar with dumpsite soil and Biochar with the control soil at $p<0.05$ (Appendix III a)

It was found that there were no significant differences in the number of leaves, leaf breadth and leaf area of Okra plant at 6WAP at $p<0.05$ (Appendix III b, d and e)

The highest leaf length of Okra plant at 6WAP was found in Dumpsite soil (5.9cm) while the lowest leaf length was found in Control soil (4.1cm). The mean values were subjected to DMRT which showed that the leaf length of okra plant in Dumpsite soil was statistically greater than the leaf length in the Biochar with Dumpsite soil and the Biochar with Control soil which were statistically the same but statistically greater than the leaf length in the Control soil at $p<0.05$ (Appendix III c). The leaf length of Okra plant at 6WAP follows this trend: DS > BD = BC >CS

The petiole length in the Okra plant at 6WAP had the highest length (5.0cm) in the Control soil while the lowest length (2.8cm) was found on Biochar with Control soil. When the means were

subjected to DMRT, there were significant differences in the petiole length in the Control soil which was greater than the petiole length in Biochar with Dumpsite soil which was statistically the same with the petiole length in the Dumpsite soil but significantly different from the petiole length in the Biochar with the Control soil at $p<0.05$ (Appendix III f).

At harvest, Table 20b showed okra plant on Dumpsite soil had 2 fruits while Biochar with control soil had the lowest number of fruits (0.6). The means were subjected to DMRT, Dumpsite soil was significantly different from the other soil treatments at $p<0.05$. Biochar with dumpsite soil had the highest fresh weight of fruit (4.2g) while Biochar with control soil had the lowest fresh weight (0.00g). When subjected to DMRT, there were no significant difference in the fresh weight of Okra fruit from Dumpsite soil and Biochar with dumpsite soil but statistically greater than the fresh weight of fruits from the Control soil and Biochar with the Control soil which were statistically the same at $p<0.05$ (Appendix III h). The weight of fresh Okra fruits follows this trend: BD = DS > CS=BC

Biochar with dumpsite soil has the highest dry weight of fruit (0.7g) while Control soil and Biochar with control soil has the lowest dry weight of fruits (0.00g). When subjected to DMRT, there were significant differences in the weight of dry Okra fruit. The dry weight of the Okra fruit from Biochar with dumpsite soil was significantly different from the ones from the Dumpsite soil which was statistically different from the Control soil and Biochar with the Control soil which were statistically the same at $p<0.05$ (Appendix III i). The dry weight of the Okra fruits follows this trend: BD > DS > CS=BC

There were no significant differences between the fresh and the dry weight of the Okra plant in all the soil samples at $p<0.05$ (Appendix III j).

Table 21 shows the growth performance for *Corchorus olitorious*. At 2WAP,it showed that the shoot height of *Cochorus olitorious* plants on the Control soil and Biochar with Control soil were statistically the same but significantly greater than those on the Control soil and those planted on Biochar with Control soil at $p<0.05$ (Appendix IV a). There were no significant differences in all the soil types with respect to their number of leaves, leaf length, leaf breadth, and leaf area at $p<0.05$ (Appendix IV b, c, d and e). The petiole length of *C. olitorious* at 2WAP showed that there were significant differences among all the soil types, the petiole length in Biochar with Control soil was significantly different from the petiole length in Dumpsite soil and Biochar with dumpsite soil which were statistically the same, but the petiole length in the Control soil was not significantly different from Biochar with Control soil and Biochar with dumpsite soil at $p<0.05$ (Appendix IV f).

Table 21 also shows the growth performances of *C. olitorious* plant at 4WAP. The highest shoot height (10.63cm) was found in *C. olitorious* plant on the Control soil while the lowest height (4.5cm) was found in Biochar with dumpsite soil. The mean was subjected to DMRT, it was found that there were significant differences in all the soil samples, the shoot height in *C. olitorious* on the Control soil were statistically greater than those in Biochar with the Control soil but not significantly different from Dumpsite soil and Biochar with Dumpsite soil at $p<0.05$ (Appendix V a) There were no significant difference in the number of leaves and leaf length in *C. olitorious* at 4WAP in the Control soil and Biochar with the Control soil which were statistically the same but there were significant differences among in them when compared with those from the Dumpsite soil and the Biochar with the Control soil which were statistically the same at $p\leq0.05$ (Appendix V b and c).

There were no significant differences in the leaf breadth in all the soil types at $p\leq0.05$

(Appendix V d). The largest leaf area of *C. olitorious* plant at 4WAP were found in Control soil (4.9cm2) while the smallest leaf area (2.05cm^2) was found in Biochar with Control soil. The mean values were subjected to DMRT which showed that the leaf area in the Control soil (4.9cm^2) was greater than those on the Dumpsite soil, Biochar with Control soil and Biochar with dumpsite soil, they were not significantly different from one another at $p \leq 0.05$ (Appendix V e). The petiole length of *C. olitorious* at 4WAP had the highest length (1.9cm) in the Control soil while the lowest length (0.6cm) was found in Biochar with dumpsite soil. When subjected to DMRT, the result showed that Dumpsite soil and Biochar with Control soil of the petiole length at 4WAP were not significantly different from the petiole length of the plant in Biochar with dumpsite soil and Control soil at $p \leq 0.05$ (Appendix V f)

Table 21 also shows the growth performances of *C. olitorious* at 6WAP. The highest shoot height was found in Biochar with Control soil (19.3cm) while the lowest shoot height was found in Biochar with Dumpsite soil (8.6cm). When the mean values were subjected to DMRT, there were no significant differences in the shoot height at $p \leq 0.05$ (Appendix VI a). The highest number of leaves (29.3) in *C. olitorious* plant at 6WAP was found in the Control soil while the lowest number of leaves (14) was found in Biochar with Dumpsite soil. When the means were subjected to DMRT, there were no significant differences in the number of leaves of *Cochorus olitorious* at 6WAP at $p \leq 0.05$ (Appendix VI b). The leaf length in *C. olitorious* at 6WAP has the highest length (5.9cm) in the Biochar with Control soil while the lowest leaf length (3.8cm) was found in Biochar with Dumpsite soil. When the means were subjected to DMRT, there were significant differences between the leaf length in the Biochar with Control and the leaf length in Biochar with dumpsite soil. The leaf length in the Control soil and Dumpsite soil were not significantly different from the leaf length in the Biochar with Control soil and Biochar with

dumpsite soil at p≤0.05 (Appendix VI c).

There were no significant differences in the leaf breadth of *C. olitorious* at 6WAP at p≤0.05 (Appendix VI d). The leaf area in *C. olitorious* at 6WAP has the largest area (6.7) in the Biochar with control soil while the lowest leaf area (3.02) was found in Biochar with Dumpsite soil. When the means were subjected to DMRT, there were significant differences between the leaf area in the Biochar with Control and the leaf area in Biochar with dumpsite soil. The leaf area in the Control soil and Dumpsite soil were not significantly different from the leaf area in the Biochar with Control soil and Biochar with dumpsite soil at p≤0.05 (Appendix VI e). The petiole length in the *C. olitorious* plant at 6WAP had the highest length (1.6cm) in the Biochar with Control soil while the lowest length (0.7cm) was found on Biochar with Dumpsite soil. When the means were subjected to DMRT, there were significant differences in the petiole length in the Biochar with Control soil and Biochar with Dumpsite soil but not significantly different from Control soil and the Dumpsite soil at p≤0.05 (Appendix VI f). At harvest, there were no significant differences in the fresh and dry weight of the plant at p≤0.05 (Appendix VI g and h).

Table 22 shows the growth performance for *Amaranthus esculentus*. At 2WAP, *A. esculentus* on the Control soil has the highest shoot height (6.0cm) while *A. esculentus* on the Biochar with the Control soil has the lowest shoot height (0.00cm). That is, at 2WAP the seeds of *A. esculentus* on Biochar with the Control soil had not germinated. It further showed that *A. esculentus* plant on dumpsite soil, Dumpsite with Biochar soil, Control soil and Biochar With Control soil were not statistically the same at p≤0.05 (Appendix VI1a). The highest number of leaves of *A. esculentus* at 2WAP was observed on the Control soil (8). The mean numbers of leaves were subjected to DMRT which showed that the number of leaves on the Control soil was statistically

greater than the number of leaves from the Dumpsite soil and Dumpsite soil with Biochar which were statistically the same at $p \leq 0.05$ (Appendix VI1b). The leaf length, leaf breadth and leaf area of *A. esculentus* plant on the Control soil was statistically greater than those from the Dumpsite soil and Dumpsite soil with Biochar which were statistically the same at $p \leq 0.05$ (Appendix VI1c, d and e). The petiole length of *A. esculentus* showed that there were significant differences in all the soil treatment at $p \leq 0.05$ (Appendix VI1f).

Table 22 shows the growth performance of *Amaranthus esculentus* at 4WAP. The highest shoot height (10.8cm) was observed in the Control soil while the lowest shoot height (4.5cm) was observed in Biochar with Control soil. When the mean shoot heights were subjected to DMRT, it was found that there were no significant differences in all the soil treatments at $p \leq 0.05$ (Appendix VIII a). The highest number of leaves (9.6) was observed in the Control soil while the lowest (5.3) was observed in the Dumpsite soil. When the mean number of leaves were subjected to DMRT, it was observed that there were significant differences among the Control soil and the Dumpsite soil, Biochar with Dumpsite soil and Biochar with the Control soil which were statistically the same at $p<0.05$ (Appendix VIII b). At 4WAP, it was observed that the leaf length of *A. esculentus* was the same in Biochar with Dumpsite soil and the Control soil. When subjected to DMRT, it was observed that there were no significant differences among the leaf length of Biochar with Dumpsite soil and the Control soil but was statistically greater than the leaf length in the Dumpsite soil and the Biochar with the Control soil which were statistically the same at $p<0.05$(Appendix VIII c).

At 4WAP the leaf breadth of *Amaranthus esculentus* in the Dumpsite soil was not significantly different from the leaf breadth of the plant in Biochar with dumpsite soil, Control soil and Biochar with the Control soil at $p<0.05$ (Appendix VIII d). There were no significant

differences in the leaf area of all the soil treatment of *A. esculentus* at 4WAP at $p< 0.05$ (Appendix VIII e). The petiole length of *A. esculentus* showed that there were significant differences among the Biochar with the Control soil and Dumpsite soil, Biochar with dumpsite soil and the Control soil which were statistically the same at $p<0.05$ (Appendix VIII f). At 6WAP, there were no significant differences in the shoot height, leaf length, leaf breadth, leaf area and petiole length in the Dumpsite soil, Biochar with the dumpsite soil, Control soil and Biochar with the Control soil at $p<0.05$ (Appendix IX a, c, d, e and f). Although the number of leaves in the Control had the highest (15) but it was not significantly different from the number of leaves in Dumpsite soil, Biochar with dumpsite soil and Biochar with the Control soil at $p<0.05$ (Appendix IX b). There was no significant difference in the fresh weight and dry weight of *A. esculentus* plants separately during the harvest at $p\leq0.05$ (Appendix IX g and h).

Table 20b: Yield attributes of Okra

At harvesting	Number of Fruits	Fresh weight of Fruits	Dry weight of Fruits	Fresh weight of Plants	Dry weight of Plants
DS	2.00 ± 0.00^{a}	3.70 ± 1.41^{a}	0.47 ± 0.15^{b}	3.40 ± 1.21^{a}	$1.50\pm.60^{a}$
BD	1.67 ± 0.58^{ab}	4.20 ± 0.20^{a}	0.70 ± 0.10^{a}	5.30 ± 2.04^{a}	0.93 ± 0.47^{a}
CS	1.00 ± 0.00^{bc}	1.07 ± 0.15^{b}	0.0 ± 0.00^{c}	4.43 ± 2.15^{a}	0.87 ± 0.57^{a}
BC	0.67 ± 0.57^{c}	0.00 ± 0.00^{b}	0.0 ± 0.00^{c}	5.60 ± 0.20^{a}	0.80 ± 0.10^{a}

Values with different superscripts along the same column are significantly different at $p< 0.05$

DS - Dumpsite Soil

BD – Biochar with Dumpsite soil

CS – Control Soil

BC – Biochar with Control soil

Table 21a: Growth Performance of *Corchorus olitorious* in different Soil Treatments.

2WAP	Shoot Height	Number of leaves	Leaf length	Leaf breadth	Leaf Area	Petiole length
DS	2.83±0.20^{c}	5.0±1.00^{a}	2.0±0.60^{a}	1.1±0.30^{a}	1.1±0.60^{a}	0.3±0.10^{b}
BD	3.17±1.00^{c}	4.67±1.50^{a}	1.9±0.80^{a}	0.93±0.10^{a}	0.9±.0.60^{a}	0.23±0.05^{b}
CS	6.0±0.43^{a}	5.67±0.60^{a}	3.0±0.90^{a}	1.57±0.30^{a}	2.31±0.70^{a}	0.46±0.15^{ab}
BC	4.7±1.60^{ab}	4.67±0.50^{a}	2.9±0.30^{a}	1.37±0.30^{a}	2.03±0.60^{a}	0.7±0.25^{a}
4WAP						
DS	7.0±0.20^{bc}	7.0±1.00^{b}	3.4±0.70^{b}	1.50±0.20^{a}	2.6±0.80^{bc}	0.80±0.20^{bc}
BD	4.5±1.50^{c}	7.0±1.00^{b}	2.6±0.80^{b}	1.47±0.40^{a}	2.0±1.21^{c}	0.60±0.00^{c}
CS	10.6±2.30^{a}	13.0±2.00^{a}	4.9±0.40^{a}	2.0±0.36^{a}	4.9±1.28^{a}	1.6±0.51^{a}
BC	9.4±0.90^{ab}	11.0±1.00^{a}	4.8±0.40^{a}	1.9±0.30^{a}	4.7±1.30^{ab}	1.47±0.40^{ab}
6WAP						
DS	10.4±0.70^{a}	15.7±4.90^{a}	4.9±0.90^{ab}	1.8±0.30^{a}	4.5±1.50^{ab}	1.1±0.15^{bc}
BD	8.6±2.26^{a}	14.0±5.00^{a}	3.8±1.80^{b}	1.5±0.50^{a}	3.02±1.80^{b}	0.7±0.25^{c}
CS	19.1±0.80^{a}	29.3±4.10^{a}	5.23±0.50^{ab}	1.7±0.17^{a}	4.43±0.30^{ab}	1.4±0.10^{ab}
BC	19.3±4.50^{a}	26.0±4.00^{a}	5.9±0.80^{a}	2.2±0.40^{a}	6.7±2.13^{a}	1.7±0.35^{a}

Values with different superscripts along the same column are significantly different at $p< 0.05$

WAP- Weeks After Planting

DS - Dumpsite Soil

BD – Biochar with Dumpsite soil

CS – Control Soil

BC – Biochar with Control soil

Table 21b: BIOMASS OF Corchorus olitorious

	Fresh weight	Dry weight
DS	4.17 ± 1.33^{a}	0.83 ± 0.41^{a}
BD	4.57 ± 2.31^{a}	0.93 ± 0.61^{a}
CS	4.43 ± 0.60^{a}	1.23 ± 0.23^{a}
BC	4.73 ± 1.72^{a}	1.07 ± 0.47^{a}

Values with different superscripts along the same column and rows are significantly different at $p< 0.05$

DS - Dumpsite Soil

BD – Biochar with Dumpsite soil

CS – Control Soil

BC – Biochar with Control soil

TABLE 22a: Growth Performance of *Amaranthus esculentus* in different Soil

2WAP	Shoot Height	Number of leaves	Leaf length	Leaf breadth	Leaf Area	Petiole length
DS	5.13±0.30^{b}	6.00±0.00^{b}	1.87±0.15^{b}	1.03±0.15^{ab}	0.97±0.22^{b}	0.53±0.06^{b}
BD	4.10±0.20^{c}	5.00±0.00^{b}	1.70±0.20^{b}	0.83±0.15^{b}	0.70±0.09^{b}	0.30±0.00^{c}
CS	6.00±0.20^{a}	8.00±0.00^{a}	2.23±0.15^{a}	1.30±0.20^{a}	1.46±0.33^{a}	0.77±0.06^{a}
BC	0.00±0.00^{d}	0.00±0.00^{c}	0.00±0.00^{c}	0.00±0.00^{c}	0.00±0.00^{c}	0.00±0.00^{d}
4WAP						
DS	8.0±5.38^{a}	5.33±0.58^{b}	3.70±0.61^{ab}	1.50±0.1^{ab}	4.17±0.74^{a}	1.0±0.00^{a}
BD	9.3±2.80^{a}	7.00±2.00^{b}	4.33±1.65^{a}	2.10±0.85^{a}	7.53±5.50^{a}	1.07±0.10^{a}
CS	10.8±2.82^{a}	9.67±1.52^{a}	4.30±1.00^{a}	2.10±0.34^{a}	6.92±2.71^{a}	1.10±0.45^{a}
BC	4.50±0.00^{a}	6.33±0.58^{b}	2.10±0.65^{b}	1.00±0.20^{b}	1.64±0.82^{a}	0.50±0.20^{b}
6WAP						
DS	14.67±7.49^{a}	10.67±2.08^{b}	6.27±1.72^{a}	2.93±0.73^{a}	14.42±6.78^{a}	2.03±0.95^{a}
BD	12.60±2.90^{a}	10.00±1.00^{b}	4.70±0.10^{a}	2.00±0.00^{a}	7.05±0.15^{a}	1.97±0.25^{a}
CS	15.70±4.25^{a}	15.00±3.60^{a}	5.10±1.15^{a}	2.23±0.49^{a}	8.79±3.82^{a}	2.23±0.25^{a}
BC	10.90±1.28^{a}	12.00±1.0^{ab}	4.17±1.30^{a}	1.90±0.65^{a}	6.36±4.00^{a}	1.17±0.55^{a}

Values with different superscripts along the same column are significantly different at $p< 0.05$

Table 22b: Biomass of *Amaranthus esculentus*

	Fresh weight	Dry weight
DS	10.43±7.12[a]	1.30±1.34[a]
BD	4.37±2.05[a]	0.47±0.06[a]
CS	7.63±3.12[a]	1.50±0.46[a]
BC	3.17±2.72[a]	0.23±0.25[a]

Values with different superscripts along the same column and rows are significantly different at $p < 0.05$

WAP- Weeks After Planting

DS - Dumpsite Soil

BD – Biochar with Dumpsite soil

CS – Control Soil

BC – Biochar with Control soil

Table 23 shows the analysis of the growth performance of *Tithonia diversifolia*. At 2WAP, *T. diversifolia* on the Control soil has the highest shoot height (8.2cm) while *T. diversifolia* on the Biochar with the dumpsite soil had the lowest shoot height (6.3cm). When the shoot height was subjected to DMRT, there was no significant difference at $p<0.05$ (Appendix X a). The highest number of leaves of *T. diversifolia* at 2WAP was observed in the Dumpsite soil (8) while the lowest (6) was observed in Biochar with dumpsite soil and the Control soil. The means of the numbers of leaves were subjected to DMRT which showed that the number of leaves in the Dumpsite soil is statistically greater than the number of leaves from the Biochar with Dumpsite soil and the Control soil which were statistically the same that is, there was no significant difference between *T. diversifolia* at 2WAP in Biochar with Dumpsite soil and the Control soil at $p<0.05$ (Appendix X b). *T. diversifolia* plant at 2WAP had the highest leaf length and leaf breadth in the Dumpsite soil which were significantly different from the Control site, Biochar with Dumpsite soil and Biochar with the control site soil which were significantly the same at $p\leq0.05$ (Appendix X c and d). There were no significant differences in the leaf area of *T. diversifolia* at 2WAP in all the soil types at $p\leq0.05$ (Appendix X e). The petiole length of *T diversifolia* showed that there were significant differences among the Dumpsite soil, and the Biochar with dumpsite soil, Control soil and Biochar with the Control soil which are separated statistically the same at $p\leq0.05$ (Appendix X f). Table 23 further shows that there were no significant differences in the shoot height, the number of leaves and the petiole length of *T. diversifolia* at 4WAP at $p\leq0.05$ (Appendix XI a, b and f). *Tithonia diversifolia* at 4WAP had the highest leaf length (6.8cm) in the Dumpsite soil while the lowest (4.3cm) in the Biochar with the Control soil. The means were subjected to DMRT and it was observed that there were significant

differences in *T. diversifolia* plant in the Dumpsite soil and the Biochar with dumpsite soil, Control soil and Biochar with dumpsite soil which were separated statistically the same at p≤0.05 (Appendix XI c). *Tithonia diversifolia* plant at 4WAP had the highest leaf breadth (3.5cm) in the Dumpsite soil while the lowest (1.4cm) was in Biochar with dumpsite soil. Separation of the means showed that there were no significant differences in the leaf breadth of *T. diversifolia* on the Biochar with dumpsite soil, Control soil and Biochar with the Control soil but the leaf breadth in the Dumpsite soil was statistically greater than those on the other soil types at p≤0.05 (Appendix XI d). *T. diversifolia* plant at 4WAP had the highest leaf breadth (15.7cm) in the Dumpsite soil while the lowest (4.7cm) was in Biochar with dumpsite soil. Separation of the means showed that there were no significant differences in the leaf breadth of *T. diversifolia* on the Biochar with dumpsite soil, Control soil and Biochar with the Control soil but the leaf breadth in the Dumpsite soil was statistically greater than those on the other soil types at p≤0.05 (Appendix XI e)

Table 23 further shows the growth performance of *Tithonia diversifolia* at 6WAP. The highest shoot height (13.1cm) was observed in the Dumpsite soil while the lowest shoot height (10.4cm) was observed in Biochar with Control soil. The means of the shoot height were subjected to DMRT, it showed that there were no significant differences in the features in all the soil types at p≤0.05 (Appendix XII a). The highest number of leaves (11.3) was observed in the Dumpsite soil and the Biochar with dumpsite soil while the lowest (10) was observed in the Control soil and Biochar with Control soil. The means of the number of leaves were subjected to DMRT, it was observed that there were no significant differences among the Control soil, the Dumpsite soil, Biochar with Dumpsite soil and Biochar with the control soil that is they are statistically the same at p≤0.05 (Appendix XII b). At 6WAP, it was observed that the leaf length, leaf breadth

and leaf area of *T. diversifolia* had the highest (7.9, 3.9 and 24.0cm), respectively in the Dumpsite soil while the lowest (5.7, 2.4 and 10.5cm), respectively in Biochar with Control soil. When subjected to DMRT, it was observed that there were no significant differences among the leaf length of Biochar with Dumpsite soil, and the Control soil and Biochar with the control soil but significantly different from the Dumpsite soil at $p \leq 0.05$ (Appendix XII c, d and e). The petiole length of *T. diversifolia* at 6WAP showed that Dumpsite soil had the highest petiole length (1.9cm) but not significantly different from those planted on Biochar with dumpsite soil, Biochar with the Control soil and Control soil at $p \leq 0.05$ (Appendix XII f).

Table 23 also shows the growth performance of *Tithonia diversifolia* at 8WAP. The highest shoot height (16.6cm) was observed in the Dumpsite soil while the lowest shoot height (11.3cm) was observed in Biochar with dumpsite soil. The means were subjected to DMRT, it showed that there were no significant differences in the shoot height in Dumpsite soil, Biochar with dumpsite soil and the Control soil but were significantly different from the shoot height in Biochar with dumpsite soil at $p \leq 0.05$. However, Biochar with Dumpsite soil and Biochar with the Control soil were statistically the same at $p \leq 0.05$ (Appendix XIII a). The highest number of leaves (16.3) was observed in the Control soil while the lowest (10) was observed in Biochar with dumpsite soil and Biochar with control soil. The means of the number of leaves were subjected to DMRT, it was observed that there were no significant differences between the Control soil and Biochar with the Control soil but are significantly greater than Dumpsite soil and Biochar with Dumpsite soil that were statistically the same at $p < 0.05$ (Appendix XIII b).

At 8WAP, it was observed that the leaf length and leaf area of *Tithonia diversifolia* had the highest (7.3 and 23.2cm) respectively in the Dumpsite soil while the lowest (5.9 and 11.3cm) respectively in Biochar with Control soil. When subjected to DMRT, it was observed that there

were no significant differences among the leaf length and leaf area of Biochar with Dumpsite soil, the Control soil and Biochar with the Control soil but significantly lower in the Dumpsite soil at $p \leq 0.05$ (Appendix XIII c and e). The leaf breadth of *T. diversifolia* at 8WAP had the highest (4.2cm) breadth in Dumpsite soil while the lowest breadth (2.5cm) was found in Biochar with Control soil. The mean were subjected to DMRT, and it showed that there were significant differences among the leaf breadth of *T. diversifolia* at 8WAP in Dumpsite soil, Control soil and Biochar with the control soil but Control soil and Biochar with Control soil were not significantly different from Biochar with dumpsite soil at $p \leq 0.05$ (Appendix XIII d) The petiole length of *T. diversifolia* at 8WAP showed that Biochar with Control soil had the highest petiole length (2.3cm) and was significantly different from those planted on Biochar with dumpsite soil, Biochar with the Control soil and Control soil which were statistically the same at $p<0.05$ (Appendix XIII f).

There were no significant difference in the fresh and dry weight of *Tithonia diversifolia* plants during the harvest at $p<0.05$ (Appendix XIII g and h).

Table 23a: GROWTH Performance of *Tithonia diversifolia*

2WAP	Shoot Height	Number of leaves	Leaf length	Leaf breadth	Leaf Area	Petiole length
DS	7.83±0.42^{a}	8.0±0.00^{a}	5.50±0.00^{a}	2.93±0.1^{a}	8.07±0.31^{a}	1.33±0.15^{a}
BD	6.33±0.85^{a}	6.00±0.00^{c}	2.80±0.40^{c}	1.03±0.06^{c}	1.45±0.28^{a}	0.53±0.06^{b}
CS	8.20±1.73^{a}	6.00±0.00^{c}	3.73±0.68^{b}	1.87±0.40^{b}	10.77±11.5^{a}	0.70±0.26^{b}
BC	6.70±1.64^{a}	7.00±1.00^{b}	3.00±0.50^{bc}	1.37±0.25^{c}	2.09±0.71^{a}	0.40±0.10^{b}
4WAP						
DS	10.30±1.21^{a}	10.0±1.00^{a}	6.83±0.49^{a}	3.50±0.46^{a}	15.76±0.71^{a}	1.23±0.06^{a}
BD	8.50±1.00^{a}	9.33±1.15^{a}	4.40±0.40^{b}	1.47±0.25^{c}	4.79±0.413^{c}	0.97±0.31^{a}
CS	10.20±1.54^{a}	9.33±1.15^{a}	5.13±1.0^{b}	2.50±0.53^{b}	9.89±3.84^{b}	0.90±0.53^{a}
BC	8.30±0.60^{a}	9.00±1.0^{a}	4.33±0.35^{b}	2.10±0.10^{bc}	6.86±0.90^{bc}	0.93±0.06^{a}
6WAP						
DS	13.17±0.28^{a}	11.33±4.9^{a}	7.90±0.65^{a}	3.9±0.46^{a}	24.05±1.55^{a}	1.97±0.55^{a}
BD	13.17±2.56^{a}	11.33±4.04^{a}	5.80±0.46^{b}	2.83±0.3^{b}	12.39±2.27^{b}	1.40±0.10^{ab}
CS	12.47±1.88^{a}	10.0±1.73^{a}	6.33±0.75^{b}	2.90±0.35^{b}	13.8±2.84^{b}	1.17±0.11^{b}
BC	10.47±1.95^{a}	10.0±0.0^{a}	5.7±0.30^{b}	2.47±0.15^{b}	10.55±1.00^{b}	1.40±0.20^{ab}
8WAP						
DS	16.67±0.76^{a}	11.33±2.52^{b}	7.30±0.36^{a}	4.20±0.10^{a}	23.23±1.66^{a}	1.73±0.25^{b}

BD	11.33±3.05^{b}	10.00±1.00^{b}	6.13±0.25^{b}	2.90±0.20^{bc}	13.37±1.47^{b}	1.63±0.06^{b}
CS	15.23±0.93^{a}	16.33±0.58^{a}	6.13±0.61^{b}	3.23±0.38^{b}	14.91±2.68^{b}	1.53±0.06^{b}
BC	13.63±1.3^{ab}	14.67±1.52^{a}	5.97±0.41^{b}	2.53±0.25^{c}	11.39±1.87^{b}	2.33±0.57^{a}

Values with different superscripts along the same column are significantly different at $p< 0.05$

Table 23b: Biomass of *Tithonia diversifolia*

At harvest	Fresh weight	Dry weight
DS	10.83±4.40^{a}	2.53±1.30^{a}
BD	6.63±0.75^{a}	1.03±0.31^{a}
CS	6.13±2.31^{a}	1.17±0.64^{a}
BC	5.73±1.75^{a}	1.27±0.49^{a}

Values with different superscripts along the same column are significantly different at $p< 0.05$

WAP- Weeks After Planting

DS - Dumpsite Soil

BD – Biochar with Dumpsite soil

CS – Control Soil

BC – Biochar with Control soil

Table 24 shows the growth performances and yield attributes of *Solanum lycopersicon*. At 2WAP, there were no significant differences in the shoot height, leaf length, leaf breadth and leaf area in all the soil types at $p<0.05$ (Appendix XIV a, c, d and e). The number of leaves in *S. lycopersicon* at 2WAP in Control soil and Biochar with control were not significantly different but were statistically greater than the number of leaves in Dumpsite soil and Biochar with dumpsite soil which are statistically the same at $p<0.05$ (Appendix XIV b). Table 24 also shows the growth parameters of *Solanum lycopersicon* at 4WAP. The highest shoot height (7.13cm) was found in Biochar with dumpsite soil but statistically the same with result in Control soil while the lowest shoot height (5.50cm) was found in Biochar with Control soil. The means were separated by DMRT and it was observed that there were no significant differences among the shoot heights of *Solanum lycopersicon* at 4WAP in Dumpsite soil, Biochar with dumpsite soil and the Control but they were significantly different from the shoot height in Biochar with Control soil at $p<0.05$ (Table 24).

The highest number of leaves (20) in *Solanum lycopersicon* at 4WAPwas observed in Control soil while the lowest (15.3) was observed in Biochar with Control soil. The means when subjected to DMRT, was found that the leaf number in Dumpsite soil was not significantly different from the leaf number in Biochar with dumpsite soil, Control soil and Biochar with the Control soil at $p<0.05$ (Table 24). The leaf length in *S. lycopersicon* at 4WAP has the highest leaf length (2.57cm) in the Control soil while the lowest length (1.13 cm) was observed in Biochar with Control soil. The means were subjected to DMRT and was observed that there were significant differences between the leaf length in Biochar with Control soil and the Control soil but the leaf length in the Control soil was not significantly different from the leaf length in Biochar with dumpsite soil and Dumpsite soil at $p<0.05$ (Table 24). The leaf breadth and leaf

area in *S. lycopersicon* at 4WAP though haD the highest leaf breadth and leaf area in the Control soil but was not significantly different from the leaf breadth in Dumpsite soil, Biochar with Dumpsite soil and Biochar with the Control soil at $p<0.05$ (Table 24).. There were significant differences in the petiole length of *Solanum lycopersicon* at 4WAP. The petiole length in Biochar with dumpsite soil was statistically greater than the petiole length in Dumpsite soil, Control soil and Biochar with Control soil at $p<0.05$ (Appendix XV f).

Table 24 further shows the growth performances of *Solanum lycopersicon* at 6WAP. The highest shoot height (10.6cm) was found in Dumpsite soil while the lowest shoot height (6.0cm) was found in Biochar with Control soil. The means were separated by DMRT and it was observed that there were no significant differences in the shoot heights of *S. lycopersicon* at 6WAP in Dumpsite soil, Biochar with dumpsite soil and Control soil, and further showed that the shoot height in Biochar with dumpsite soil are not significantly different from Biochar with Control soil at $p<0.05$ (Table 24). The highest number of leaves (36) in *Solanum lycopersicon* at 6WAP was observed in Dumpsite soil while the lowest (19) was observed in Biochar with dumpsite soil. The means were subjected to DMRT, and was found that the leaf number in Dumpsite soil was not significantly different from the leaf number in Control soil and Biochar with Control soil but significantly different from Biochar with dumpsite soil $p<0.05$ (Table 24). The leaf length, leaf breadth and leaf area in *S. lycopersicon* at 6WAP when subjected to DMRT showed that there were no significant differences in each attributes in all the soil types at $p<0.05$ (Appendix XVI c, d and e). The petiole length in Dumpsite soil is longer than every other one, but the petiole length in Biochar with dumpsite soil, Biochar with Control soil and Control soil were statistically the same in their petiole length at $p<0.05$ (Appendix XVI f).

Table 24a: Analysis of growth performance for *Solanum lycopersicon*

2WAP	Shoot Height	Number of leaves	Leaf length	Leaf breadth	Leaf Area	Petiole length
DS	4.70±0.82^{a}	6.00±2.00^{c}	1.07±0.21^{a}	0.80±0.26^{a}	0.66±0.28^{a}	
BD	5.27±0.25^{a}	6.33±1.53^{bc}	0.87±0.15^{a}	0.73±0.15^{a}	0.49±0.18^{a}	
CS	5.47±1.28^{a}	9.67±1.53^{a}	1.23±0.25^{a}	2.60±2.95^{a}	0.77±0.34^{a}	
BC	3.87±0.57^{a}	9.33±1.53^{ab}	1.03±0.21^{a}	0.57±0.11^{a}	0.45±0.17^{a}	
4WAP						
DS	6.87±0.23^{a}	18.00±1.73^{ab}	2.03±0.47^{a}	1.13±0.23^{a}	1.77±0.70^{ab}	0.60±0.00^{d}
BD	7.13±0.15^{a}	16.00±2.00^{b}	1.90±0.30^{a}	0.93±0.06^{a} ^{b}	1.32±0.15^{bc}	1.60±0.10^{a}
CS	7.10±1.15^{a}	20.00±3.00^{a}	2.57±0.35^{a}	1.30±0.20^{a}	2.54±0.72^{a}	1.40±0.10^{b}
BC	5.50±0.50^{b}	15.33±0.58^{b}	1.13±0.23^{b}	0.50±0.36^{b}	0.39±0.25^{c}	1.13±0.15^{c}
6WAP						
DS	10.63±1.4^{a}	36.0±2.64^{a}	2.57±0.29^{a}	1.43±0.40^{a}	2.81±1.06^{a}	2.17±0.15^{a}
BD	8.37±0.9^{a} ^{b}	19.67±4.51^{b}	1.90±0.10^{a}	1.00±0.0^{a}	1.43±0.08^{a}	1.60±.40^{ab}
CS	10.0±2.78^{a}	33.00±8.54^{a}	2.50±1.05^{a}	1.37±0.60^{a}	2.88±2.30^{a}	1.67±0.6^{a} ^{b}
BC	6.00±1.00^{b}	25.33±6.03^{ab}	1.77±0.30^{a}	1.10±0.20^{a}	1.49±0.52^{a}	1.30±0.10^{b}
8WAP						
DS	22.2±2.58^{a}	65.33±8.96^{a}	2.80±0.36^{a}	1.50±0.36^{a}	3.18±1.06^{a}	2.50±0.00^{a}
BD	12.8±2.48	49.67±11.50	2.57±0.25^{ab}	1.30±0.20^{a}	2.53±0.63^{ab}	1.87±0.7^{a}

	b	b		b		b
CS	20.00±2.0 a	71.33±3.05[a]	2.10±0.20[b]	1.00±0.20[b]	1.56±0.17[b]	2.10±0.2[a] b
BC	12.50±2.1 b	27.00±2.65[c]	2.00±0.35[b]	1.10±0.10[a] b	1.65±0.32[b]	1.50±0.50 b
10WAP						
DS	25.63±3.9 a	88.3±44.81[a]	2.73±0.46[a]	1.57±0.35[a]	3.27±1.02[a]	2.53±0.06 a
BD	17.77±2.4 b	51.67±11.9[a]	2.77±0.15[a]	1.37±0.35[a]	2.61±0.59[ab]	2.00±0.6[a] b
CS	20.4±2.9[a] b	56.67±12.74 a	2.43±0.21[a]	1.30±0.26[a]	1.85±0.25[b]	2.17±0.2[a] b
BC	17.60±2.3 b	72.33±5.86[a]	2.23±0.40[a]	1.37±0.06[a]	1.82±0.35[b]	1.67±0.45 b
12WAP						
DS	32.5±3.97 a	118.0±71.08 a	2.87±0.42[ab]	1.40±0.36[a]	3.08±1.11[ab]	2.17±0.29 a
BD	20.7±1.75 b	54.0±4.00[a]	3.20±0.00[a]	1.70±0.00[a]	4.08±0.00[a]	2.23±0.60 a
CS	24.1±5.23 b	58.0±9.00[a]	2.83±0.25[ab]	1.60±0.00[a]	3.40±0.30[ab]	2.0±0.36[a]
BC	23.8±3.3[b]	103.7±4.5[a]	2.67±0.15[b]	1.40±0.20[a]	2.79±0.55[b]	2.50±0.10 a
14WAP						
DS	40.63±6.8 a	146.67±52.3 a	2.70±0.46[b]	1.57±0.35[a] b	3.22±1.18[b]	2.27±0.5[b] c
BD	31.4±2.0[a] b	80.7±5.68[b]	3.63±0.15[a]	1.90±0.10[a]	5.17±0.07[a]	2.87±0.60 ab
CS	27.4±9.37 b	91.7±20.5[ab]	2.93±0.47[b]	1.60±0.30[a] b	3.59±1.18[b]	1.60±0.30 c

BC	30.0±0.0[a] [b]	144.0±0.0[a]	2.90±0.00[b]	1.40±0.00[b]	3.05±0.00[b]	3.50±0.00 [a]

Values with different superscripts along the same column are significantly different at $p< 0.05$

Table 24b: Yield attributes of *Solanum lycopersicon*

At harvest	Number of fruits	Fresh weight of fruit	Fresh weight of plants	Dry weight of plants
DS	6	1.8±0.0[a]	8.88±1.09[a]	2.03±0.40[b]
BD	2	0.0±0.0[d]	8.93±4.3[a]	1.57±0.40[b]
CS	2	0.6±0.0[c]	6.45±1.25[a]	2.30±0.10[ab]
BC	6	1.5±0.06[b]	11.3±3.20[a]	2.97±0.71[a]

Values with different superscripts along the same rows and column are significantly different at $p< 0.05$

WAP- Weeks After Planting

DS - Dumpsite Soil

BD – Biochar with Dumpsite soil

CS – Control Soil

BC – Biochar with Control soil

Table 24 shows the growth performances of *Solanum lycopersicon* at 8WAP. The highest shoot height (22.2cm) was found in Dumpsite soil while the lowest shoot height (12.5cm) was found in Biochar with control soil. When the means were separated with DMRT, it was observed that there were no significant differences among the shoot height of *S. lycopersicon* at 8WAP in Dumpsite soil and the Control soil but were significantly different from the shoot height in Biochar with dumpsite soil and Biochar with control soil which were statistically the same at $p<0.05$ (Table 24). The highest number of leaves (71.3) in *S. lycopersicon* at 8WAP was observed in Control soil while the lowest (27) was observed in Biochar with control soil. When the means were subjected to DMRT, it was found that the leaf number in Dumpsite soil was not significantly different from the leaf number in Control soil which was statistically higher than the leaf number in Biochar with dumpsite soil and Biochar with the control soil which were significantly different at $p<0.05$ (Appendix XVII b).

The leaf length in *S. lycopersicon* at 8WAP has the highest length (2.8cm) in the Dumpsite soil while the lowest length (2.0cm) was observed in Biochar with control soil. When the means were subjected to DMRT, it was observed that there were significant differences in the leaf length in Dumpsite soil and Biochar with control soil and the Control soil which were the same statistically but the leaf length in Biochar with dumpsite soil was not significantly different from Dumpsite soil, Control soil and Biochar with control soil at $p<0.05$ (Appendix XVII c). The leaf breadth, leaf area and petiole length in *S. lycopersicon* at 8WAP had the highest values in the Dumpsite soil but those planted on Biochar with dumpsite soil, Control soil and Biochar with the Control soil were not significantly different from those planted on the Dumpsite soil at $p<0.05$ (Appendix XVII d, e and f).

Table 24 also shows the growth parameters of *Solanum lycopersicon* at 10WAP. The highest shoot height (25.6cm) was found in Dumpsite soil while the lowest shoot height (17.6cm) was found in Biochar with Control soil. When the means were separated by DMRT, it was observed that there was significant difference between the shoot height of *S. lycopersicon* at 10WAP in Dumpsite soil and other soil which were not statistically the same at $p<0.05$ (Appendix XVIIIa). The highest number of leaves (88.3) in *S. lycopersicon* at 10WAP was observed in Dumpsite soil while the lowest (51) was observed in Biochar with dumpsite soil. When the means were subjected to DMRT, it was found that there were no significant differences in the number of leaves of *S. lycopersicon* at 10WAP in all the soils at $p<0.05$ (Appendix XVIII b). There were no significant differences in the leaf length and breadth of *S. lycopersicon* at 10WAP at $p<0.05$ (Appendix XVIII c and d).

The leaf area of *S. lycopersicon* at 10WAP was highest in the Dumpsite soil. When the values were subjected to DMRT, it was found that there were significant differences in the leaf area of the plants on the Dumpsite soil, Control soil and Biochar with the Control soil which were not significantly different while the leaf area in Biochar with dumpsite soil was not significantly different from those planted on the Dumpsite soil, at $p<0.05$ (Table 24). The petiole length of *S. lycopersicon* at 10WAP has the highest length (2.5cm) in Dumpsite soil while the lowest length (1.6cm) was found in Biochar with dumpsite soil. When the means were subjected to DMRT, it was found that the petiole length in Biochar with dumpsite soil and Control soil were statistically the same but were significantly shorter than the petiole length in Dumpsite soil and statistically the same with Biochar with Control soil at $p<0.05$ (Appendix XVIII f).

Table 24 also shows the growth performance of *S. lycopersicon* at 12WAP. The highest shoot height (32.5cm) was found in Dumpsite soil while the lowest shoot height (20.7cm) was found in

Biochar with Dumpsite soil. When the means were separated by DMRT, it was observed that there were significant differences in the shoot height of *S. lycopersicon* at 12WAP in Dumpsite soil and Biochar with dumpsite soil, Control soil and Biochar with Control soil which were statistically the same at $p<0.05$ (Appendix XIX a). The highest number of leaves (118.0) in *Solanum lycopersicon* at 12WAP was observed in Dumpsite soil while the lowest (54) was observed in Biochar with dumpsite soil. When the means were subjected to DMRT, it was found that there were no significant differences in the number of leaves of *S.lycopersicon* at 12WAP in Dumpsite soil, Biochar with dumpsite soil, Control soil and Biochar with control soil at $p<0.05$ (Appendix XIX b).

The leaf length in *Solanum lycopersicon* at 12WAP has the highest length (3.20cm) in Biochar with dumpsite soil while the lowest (2.67cm) was found in Biochar with Control soil. When subjected to DMRT, the leaf length in Dumpsite soil and Control soil were statistically the same but they were not significantly different from the leaf length in Biochar with dumpsite soil andwhich in turn was statistically the same with plants in Biochar with control soil at $p\leq0.05$ (Appendix XIX c). There was no significant differences in the leaf breadth and the petiole length of *S. lycopersicon* at 12WAP among the Dumpsite soil, Biochar with dumpsite soil, Control soil and Biochar with control soil at $p\leq0.05$ (Appendix XIX d and f). The leaf area in *S. lycopersicon* at 12WAP has the highest area (4.08) in Biochar with dumpsite soil while the lowest (2.7) was found in Biochar with Control soil. When subjected to DMRT, the leaf length in Dumpsite soil and Biochar with control soil were statistically the same but the leaf area in Control soil was not significantly different from the leaf area of the plants in Dumpsite soil, Biochar with dumpsite soil and Biochar with control soil at $p\leq0.05$ (Appendix XIX e). Table 24 further shows the growth parameters of *S. lycopersicon* at 14WAP. The highest shoot height (40.63cm) was found

in Dumpsite soil while the lowest shoot height (27.40cm) was found in Control soil. When the means were separated by DMRT, it was observed that there were significant differences between the shoot height of *S. lycopersicon* at 14WAP in Dumpsite soil, Control soil and Biochar with control soil which were not significantly different while the shoot height in Biochar with dumpsite soil was not significantly different from those in the Dumpsite soil, Control soil and Biochar with control soil at $p \leq 0.05$ (Appendix XX a).

The highest number of leaves (146.67) in *S. lycopersicon* at 14WAP was observed in Dumpsite soil while the lowest (80.70) was observed in Biochar with dumpsite soil. When the means were subjected to DMRT, it was found that Dumpsite soil and Biochar with Control soil which were statistically the same but significantly different from Biochar with dumpsite soil while the number of leaves in Control soil was not significantly different from Dumpsite soil, Biochar with dumpsite soil and Biochar with control soil at $p \leq 0.05$ (Appendix XX b). The leaf length and leaf area in *S. lycopersicon* at 14WAP had the highest values (3.63cm and 5.17) in Biochar with dumpsite soil, respectively. When subjected to DMRT, it was found that the leaf length and leaf area in Dumpsite soil and Control soil and Biochar with the Control soil were statistically the same but significantly lower than the leaf length and leaf area in Biochar with dumpsite soil at $p \leq 0.05$ (Appendix XX c and e). The leaf breadth in *S. lycopersicon* at 14WAP had the highest length (1.90cm) in Biochar with dumpsite soil while the lowest (1.40cm) was found in Biochar with Control soil. When subjected to DMRT, it showed that Biochar with dumpsite soil was significantly different from Biochar with Dumpsite soil and Control soil which were statistically the same at $p \leq 0.05$ (Appendix XX d). The petiole length in *S. lycopersicon* at 14WAP had the highest length (3.50cm) in Biochar with control soil while the lowest length (1.60cm) was found in the Control soil. When the means were subjected to DMRT, it showed

that the petiole length in Biochar with control soil was significantly longer than the plant from that of the Control soil. Dumpsite soil and Biochar with dumpsite soil at $p \leq 0.05$ (Appendix XX f). At the termination of the experiment, Dumpsite soil and Biochar with control soil had the highest number fruits (6) while Biochar with dumpsite soil and Biochar with control soil had (2). The fresh fruit of *S. lycopersicon* had the highest weight (1.8g) in the dumpsite soil and the lowest weight (0.0g) in Biochar with dumpsite soil. When the mean of the fresh weight of *S. lycopersicon* were subjected to DMRT, there were significant differences in the weight of the fruits at $p \leq 0.05$ (Appendix XX g). The fresh *S. lycopersicon* plants had the highest weight (11.30g) in Biochar with control soil while the lowest weight (6.45g) was found in the Control soil. When subjected to DMRT, there were no significant difference in the weights of the plants at $p \leq 0.05$ (Appendix XX h). The dry matter of *S. lycopersicon* had the highest weight (2.97g) in Biochar with Control soil while the lowest weight (1.57g) was found in Biochar with dumpsite soil. When subjected to DMRT, it showed that the dry matter weight in Biochar with control soil as the highest and was significantly greater than the weight of the dry matter in Biochar with dumpsite soil and Dumpsite soil, while the weight of the dry matter in the Control soil was not significantly different from the Biochar with dumpsite soil, Biochar with control soil and Control soil at $p \leq 0.05$ (Appendix XX).

The concentration of heavy metals in the crops raised on dumpsite soil, Biochar with dumpsite soil, Control soil and Biochar with Control soil are shown in Table 25. In *Abelmoschus esculentum*, Cd has the highest concentration (2.78mg/kg) in the shoot of the crop on Dumpsite soil while the lowest concentration (0.82mg/kg) was found in the Control soil. When subjected to DMRT, it was found that there were significant differences in the Cd concentrations in the shoot of the crop. Cd concentration in Dumpsite soil is significantly different from its concentration in

Biochar with dumpsite soil, while Cd concentration in the Control soil and Biochar with Control soil were statistically the same at $p \leq 0.05$ (Appendix E i a.).

Cd concentration in the shoot of *Abelmoschus esculentum* followed this trend:

DS >BD > CS=BC

Cd concentration in the root of *Abelmoschus esculentum* has the highest concentration (3.07mg/kg) in the Dumpsite soil with the lowest concentration (1.1mg/kg) found in the Control soil. When subjected to DMRT, there were significant differences in the Cd concentrations in the root of *Abelmoschus esculentum* at $p<0.05$ (Appendix Eii a).

Cd concentration in the root of *Abelmoschus esculentum* followed this trend:

DS >BD > BC > CS.

The concentration of Pb in *Abelmoschus esculentum* shoot showed that Pb has the highest concentration (25.03 mg/kg) in the dumpsite soil while the lowest concentration (13.59mg/kg) was found in the Control soil. When subjected to DMRT, there were significant differences in the Pb concentration in the shoot of *Abelmoschus esculentum* at $p<0.05$ (Appendix E i b).

Pb concentration in the shoot of *Abelmoschus esculentum* followed this trend:

DS >BD > BC > CS.

Pb concentration in the root of *Abelmoschus esculentum* has the highest concentration (499.6mg/kg) in the Dumpsite soil with the lowest concentration (27.4mg/kg) found in Biochar with Control soil. When subjected to DMRT, there were significant differences in the Pb concentration in the root of *Abelmoschus esculentum* at $p<0.05$ (Appendix Eii a).

TABLE 25.Heavy metal content (mg/kg) in the harvested crops

Plants	Shoot	Cd	Pb	Ni	Fe	Cu	Zn
	DS	2.78±0.11[a]	25.0±0.03[a]	11.45±0.04[b]	1002.3±0.05[a]	24.22±0.09[a]	178.82±0.26[b]
	BD	2.36±0.03[b]	16.8±0.06[b]	7.28±0.05[c]	418.7±0.16[d]	19.29±0.02[d]	178.35±0.25[c]
	CS	0.82±0.06[c]	13.59±0.22[d]	12.34±0.10[a]	986.3±0.02[b]	21.32±0.01[c]	110.12±0.00[d]
	BC	0.87±0.05[c]	15.12±0.01c	7.29±0.00[c]	497.20±0.13[c]	21.56±0.21[b]	180.43±0.09[a]
	Root						
Abelmoschus esculentum	DS	3.07±0.16[a]	499.6±0.0[a]	11.3±0.12[a][b]	4350.98±0.99[c]	824.18±0.10[a]	596.16±0.00[d]
	BD	2.49±0.26[b]	136.72±0.2[b]	11.7±0.05[a][b]	4546.22±0.13[b]	302.65±0.09[b]	576.17±0.06[a]
	CS	1.14±0.09[d]	27.7±0.09[c]	21.8±0.08[a]	3156.5±0.155[d]	51.52±0.12[c]	110.45±0.16[c]
	BC	1.80±0.00[c]	27.19±0.00[d]	7.83±13.56[b]	6764.50±0.2[a]	3.66±0.14[d]	221.10±0.10[b]
	Shoot						
	DS	2.23±0.30[a]	54.10±1.04[a]	3.65±3.16[a]	319.0±1.57[a]	18.83±0.25[a]	151.2±1.66[a]
	BD	0.90±0.00[b]	5.29±0.07[b]	0.00±0.0[b]	112.3±0.0[d]	5.58±0-87[d]	51.77±0.19[c]
	CS	0.91±0.04[b]	0.00±0.00[c]	5.10±0.36[a]	232.39±0.31[b]	14.06±0.44[b]	51.44±0.09[c]
	BC	0.93±0.15[b]	5.20±0.35[b]	0.00±0.00[b]	167.32±0.22[c]	6.93±0.12[c]	56.87±0.91[b]
	Root						
Corchorus olitorious	DS	4.83±0.06[a]	53.61±0.04[a]	15.66±0.12[c]	9945.22±28.9[b]	1643.7±0.35[a]	782.59±8.43[a]
	BD	3.23±0.03[b]	29.27±0.23[bc]	21.70±0.10[a]	8092.72±0.08[d]	506.25±0.54[b]	593.35±0.25[b]

	CS	0.89±0.00[d]	27.43±0.56[c]	18.16±0.24[b]	9708.31±8.32[c]	66.91±0.26[c]	118.46±0.49[d]
	BC	1.35±0.21c	32.02±3.04[b]	12.28±0.23[d]	10991.3±.07[a]	40.89±0.23[d]	155.16±0.10[c]
	Shoot						
	DS	2.29±0.15[a]	18.01±0.17[c]	12.27±0.07[d]	496.43±3.29[d]	49.15±0.15[a]	267.99±2.09[a]
	BD	2.35±0.11[a]	3.14±0.04[d]	40.39±0.32[b]	828.6±0.96[c]	35.95±0.34[b]	243.85±0.40[b]
	CS	2.39±0.05[a]	40.09±0.62[a]	172.24±0.8[a]	1836.21±4.35[a]	30.87±0.16[d]	130.81±0.09[d]
	BC	2.24±0.28[a]	27.67±0.49[b]	13.46±0.37[c]	956.51±0.41[b]	33.08±0.05[c]	134.29±0.23[c]
	Root						
Amaranthus esculentum	DS	1.16±0.09[c]	350.8±2.75[a]	20.89±0.33[c]	11635.37±.38[a]	817.94±0.50[a]	643.71±0.24[a]
	BD	3.03±0.0[a]	95.31±3.00[b]	87.06±0.50[a]	1027.23±0.82[d]	109.99±3.42[b]	180.8±3.07[b]
	CS	0.95±0.11[d]	39.87±0.42[c]	63.78±2.84[b]	6599.29±5.61[b]	31.49±.12[c]	61.5400±.27622c
	BC	2.3±0.58[b]	22.17±0.1[d]	14.47±.1[d]	6240.67±53.3[c]	25.75±.63[d]	34.30±.23[d]
	Shoot						
	DS	5.2±.20[a]	40.19±1.16[a]	42.2±.36[a]	999.90±1.18[a]	12.60±.20[d]	151.75±.45[a]
	BD	3.7±.25[b]	39.28±.14[a]	24.30±.20[c]	712.09±.55[c]	34.73±1.47[a]	147.3±.46[b]
	CS	2.31±.11[c]	40.38±.26[a]	8.56±.77[d]	647.50±1.24[d]	21.26±.11[b]	99.77±.59[c]
	BC	.97±.06[d]	39.95±.26[a]	31.70±.62[b]	740.10±.26[b]	16.83±.21[c]	75.37±.60[d]
	Root						
Tithonia	DS	4.49±.1	508.92±.96	743.79±.4	6696.09±79	713.65±18.	1264.87±

diversifolia		5[a]	[a]	9[a]	.94[b]	99[a]	5.25[a]
	BD	3.47±.06[b]	137.33±1.70[b]	14.27±.11[d]	3400.43±54.20[d]	205.87±.29[b]	267.38±.19[b]
	CS	2.36±.12[c]	50.14±.35[c]	23.15±.35[c]	4957.61±24.39[c]	40.93±.23[c]	69.19±.44[d]
	BC	1.70±.00[d]	40.57±.40[d]	23.85±.41[b]	7002.93±12.07[a]	34.97±.20[c]	91.76±.43[c]
	Shoot						
	DS	3.56±.19	39.50±.33	77.5±.35	508.18±.43[c]	41.16±.11[a]	308.57±1.59[a]
	BD	2.43±.11	21.80±.17	14.95±.24	508.97±3.41[c]	40.50±.26[a]	289.61±2.23[b]
	CS	ND.	.ND	.ND	695.58±1.29[a]	35.10±.52[c]	79.77±1.65[c]
	BC	ND.	.ND	.ND	602.76±.75[b]	38.90±.78[b]	8.00±.15[d]
	Root						
Solanum lycopersicon	DS	4.73±.19	613.77±1.12	157.30±.56	10248.9±42.90[a]	4698.25±44[a]	1310.07±10.40[a]
	BD	4.60±.35	330.97±.55	23.23±.17	7170.83±93.18[b]	1041.00±2.11[b]	1153.22±1.82[b]
	CS	ND.	ND.	ND.	878.10±1.31[c]	1029.56±8.45[c]	129.31±1.28[c]
	BC	2.31±.11	7.27±12.59	14.25±.15	495.19±1.29[d]	11.31±.14[d]	22.73±.37[d]
Abelmoschus esculentum fruit	DS	2.52±.12[a]	22.17±.11[a]	14.47±.11[b]	338.83±1.46[a]	18.43±.11[a]	70.10±.87[d]
	BD	2.34+063[b]	.00±.00[c]	11.08±.30[c]	221.63±.19[c]	13.10±.16[c]	73.74±2.04[c]
	CS	1.65±.06[c]	.00±.00[c]	15.27±.07[a]	220.69±.21[c]	16.46±.30b	110.20±1.15a
	BC	1.71±.06[c]	21.06±.06[b]	14.25±.14[b]	258.63±2.94[b]	10.83±.45[d]	82.19±.33[b]

DS - Dumpsite Soil

BD – Biochar with Dumpsite soil

CS – Control Soil

BC – Biochar with Control soil

Pb concentration in the root of *Abelmoschus esculentum* followed this trend:

DS >BD > CS > BC.

Ni concentration in *Abelmoschus esculentum* shoot showed that Ni has the highest concentration (25.3 mg/kg) in the Control soil while the lowest concentration (7.28mg/kg) was found in the Biochar with dumpsite soil. When subjected to DMRT, Ni concentration in the Control soil was significantly different from the Ni concentration in Dumpsite soil while Ni concentration in Biochar with dumpsite soil and Biochar with Control soil were not significantly different at $p<0.05$ (Appendix E i c).

Ni concentration in the shoot of *Abelmoschus esculentum* followed this trend:

CS >DS >BC=BD

Ni concentration in the root of *Abelmoschus esculentum* has the highest concentration (21.7mg/kg) in the Control soil with the lowest concentration (7.8mg/kg) found in Biochar with Control soil. When subjected to DMRT, the Ni concentration in Dumpsite soil and Biochar with dumpsite soil were statistically the same, but they were not significantly different from the Ni concentration in the Control soil and Biochar with control soil at $p<0.05$ (Appendix Eii c).

Ni concentration in the root of *Abelmoschus esculentum* followed this trend:

CS > BD =DS>BC.

Fe has the highest concentration (1002mg/kg) in the shoot of the crop on Dumpsite soil while the lowest concentration (418mg/kg) was found in the Biochar with dumpsite soil. When subjected to DMRT, it was found that Fe concentration in the shoot of *A. esculentum* were significantly different at $p<0.05$ (Appendix E i d.). Fe concentration in the shoot of *Abelmoschus esculentum* follows this trend: DS > CS>BC>BD. Fe concentration in the root of *Abelmoschus esculentum* has the highest concentration (6764.5mg/kg) in Biochar with control soil while the lowest concentration (3156.5mg/kg) was found in the Control soil. When subjected to DMRT, there were significant differences in Fe concentration in the root of *A. esculentum* at $p<0.05$ (Appendix Eii d). Fe concentration in the root of *Abelmoschus esculentum* follows this trend:
BC >BD > DS > CS.

Cu has the highest concentration (24.2mg/kg) in the shoot of *Abelmoschus esculentum* in the Dumpsite soil while the lowest concentration (19.2mg/kg) was found in the Biochar with dumpsite soil. When subjected to DMRT, it was found that Cu concentrations in the shoot of *A. esculentum* were significantly different at $p<0.05$ (Appendix E i e.). Cu concentration in the shoot of *A. esculentum* followed this trend: DS >BC>CS>BD. Cu concentration in the root of *A. esculentum* was highest (824.19mg/kg) in Dumpsite soil while the lowest concentration (3.66mg/kg) was found in the Biochar with Control soil. When subjected to DMRT, there were significant differences in Cu concentration in the root of *A. esculentum* at $p<0.05$ (Appendix Eii e).Cu concentration in the root of *A. esculentum* followed this trend: DS >BD > CS >BC.

The highest concentration of Zn (180.43mg/kg) in the shoot of *A. esculentum* was found in Biochar with control soil while the lowest concentration (110.12mg/kg) was found in the Control soil. When subjected to DMRT, it was found that Zn concentration in the shoot of *Abelmoschus esculentum* were significantly different at $p<0.05$ (Appendix E i f.). Zn concentration in the shoot

of *Abelmoschus esculentum* followed this trend: BC>DS>BD >CS.

Zn concentration in the root of *Abelmoschus esculentum* has the highest concentration (576.17mg/kg) in Biochar with dumpsite soil while the lowest concentration (59.16mg/kg) was found in the Dumpsite soil. When subjected to DMRT, there were significant differences in Zn concentration in the root of *A. esculentum* at $p<0.05$ (Appendix Eii f). Zn concentration in the root of *Abelmoschus esculentum* followed this trend: BD > BC >CS> DS.

Table 25 also shows the concentration of heavy metals in *Corchorus olitorious.* Cd has the highest concentration (2.23mg/kg) in the shoot of the crop on Dumpsite soil while the lowest concentration (0.90mg/kg) was found in the Biochar with dumpsite soil. When subjected to DMRT, it was found that there were significantly differences in the Cd concentrations in the shoots of the crop. Cd concentration in Dumpsite soil was significantly different from its concentration in Biochar with dumpsite soil, Control soil and Biochar with Control soil were statistically the same at $p<0.05$ (Appendix E iii a.).

Cd concentration in the shoot of *Corchorus olitorious* followed this trend: DS >BD = CS=BC

Cd concentration in the root of *Corchorus olitorious* has the highest concentration (4.8mg/kg) in the Dumpsite soil while the lowest concentration (0.89mg/kg) was found in the Control soil. When subjected to DMRT, there were significant differences in the Cd concentration in the root of *C. olitorious* at $p<0.05$ (Appendix E iv a).

Cd concentration in the root of *C. olitorious* followed this trend: DS >BD > BC > CS.

The concentration of Pb in *Corchorus olitorious* shoot showed that Pb has the highest concentration (54.1 mg/kg) in the Dumpsite soil while the lowest concentration (0.00mg/kg) was

found in the Control soil. When subjected to DMRT, there were significant differences in the Pb concentration in the shoots of *C. olitorious.* Pb concentration in Dumpsite soil was significantly different from Biochar with dumpsite soil and Biochar with the control soil which are statistically the same but significantly different from the Pb content in the Control soil at $p<0.05$ (Appendix E iii b). Pb concentration in the shoot of *C. olitorious* followed this trend: DS >BD = BC > CS. Pb concentration in the root of *Corchorus olitorious* has the highest concentration (53.6mg/kg) in the Dumpsite soil with the lowest concentration (27.4mg/kg) found in the Control soil. When subjected to DMRT, there were significant differences in the Pb concentration in the root of *C. olitorious* at $p<0.05$ (Appendix Eiv b). Pb concentration in the root of *C. olitorious* followed this trend: DS >BC > BD > CS.

Ni concentration in *Corchorus olitorious* shoot showed that Ni has the highest concentration (5.1mg/kg) in the Control soil while the lowest concentration (0.0mg/kg) was found in Biochar with dumpsite soil and Biochar with control soil. When subjected to DMRT, Ni concentration in the Control soil was significantly different from the Ni concentration in Dumpsite soil while Ni concentration in Biochar with dumpsite soil and Biochar with Control soil were not significantly different at $p<0.05$ (Appendix E iii c). Ni concentration in the shoot of *C. olitorious* followed this trend: CS >DS >BC=BD. Ni concentration in the root of *C. olitorious* has the highest concentration (21.7mg/kg) in the Biochar with dumpsite soil while the lowest concentration (12.2mg/kg) found in Biochar with Control soil. When subjected to DMRT, the Ni concentration were significantly different at $p<0.05$ (Appendix E iv c). Ni concentration in the root of *C. olitorious* followed this trend: BD > CS > DS>BC.

Fe has the highest concentration (319.0mg/kg) in the shoot of *Corchorus olitorious* on Dumpsite soil while the lowest concentration (112.3mg/kg) was found in the Biochar with dumpsite soil.

When subjected to DMRT, it was found that Fe concentration in the shoot of *C. olitorious* were significantly different at $p<0.05$ (Appendix E iii d.). Fe concentration in the shoot of *Cochorus olitorious* followed this trend: DS > CS>BC>BD.

Fe concentration in the root of *C. olitorious* has the highest concentration (10991.3mg/kg) in Biochar with control soil while the lowest concentration (8092.0mg/kg) was found in the Biochar with dumpsite soil. When subjected to DMRT, there were significant differences in Fe concentration in the root of *C. olitorious* at $p<0.05$ (Appendix E iv d). Fe concentration in the root of *C. olitorious* followed this trend: BC > DS > CS >BD

Cu has the highest concentration (18.83mg/kg) in the shoot of *Corchorus olitorious* in the Dumpsite soil while the lowest concentration (5.58mg/kg) was found in the Biochar with dumpsite soil. When subjected to DMRT, it was found that Cu concentration in the shoot of were significantly different at $p<0.05$ (Appendix E iii e.). Cu concentration in the shoot of *C. olitorious* followed this trend: DS >CS>BC>BD. Cu concentration in the root of *C. olitorious* has the highest concentration (1643.7mg/kg) in Dumpsite soil while the lowest concentration (40.89mg/kg) was found in the Biochar with Control soil. When subjected to DMRT, there were significant differences in Cu concentration in the root of *C. olitorious* at $p<0.05$ (Appendix E iv e). Cu concentration in the root of *Corchorus olitorious* followed this trend: DS >BD > CS >BC

The highest concentration of Zn (151.2mg/kg) in the shoot of *Cochorus olitorious* was found in Dumpsite soil while the lowest concentration (51.4mg/kg) was found in the Control soil. When subjected to DMRT, it was found that Zn concentration in Dumpsite soil was significantly different from the Zn concentration in Biochar with Control soil which was significantly different from its concentration in Biochar with dumpsite soil and Control soil which was statistically the same at $p<0.05$ (Appendix E iii f.).

Zn concentration in the shoot of *Corchorus olitorious* followed this trend: DS> BC >BD =CS Zn concentration in the root of *C. olitorious* has the highest concentration (782.59mg/kg) in Dumpsite soil while the lowest concentration (118.46mg/kg) was found in the Control soil. When subjected to DMRT, there were significant difference in Zn concentration in the root of *C. olitorious* at $P<0.05$ (Appendix E iv f).

Zn concentration in the root of *C. olitorious* followed this trend: DS > BD >BC > CS.

Furthermore, Table 25 shows the concentration of heavy metals in *Amaranthus esculentus.* Cd has the highest concentration (2.39mg/kg) in the shoot of *A. esculentus* in the Control soil while the lowest concentration (2.24mg/kg) was found in Biochar with Control soil. When subjected to DMRT, it was found that there were no significant difference in the level of Cd concentration in the shoot of *A. esculentus* at $p<0.05$ (Appendix E v a.).

Cd concentration in the shoot of *A. esculentus* followed this trend: DS =BD = CS=BC

Cd concentration in the root of *Amaranthus esculentus* has the highest concentration (3.03mg/kg) in Biochar with dumpsite soil while the lowest concentration (0.95mg/kg) was found in the Control soil. When subjected to DMRT, there were significant differences in the Cd concentration in the root of *A. esculentus* at $p<0.05$ (Appendix E vi a).

Cd concentration in the root of *Amaranthus esculentus* follows this trend: BD > BC > DS > CS.

The concentration of Pb in *A. esculentus* shoot shows that Pb has the highest concentration (40.09mg/kg) in the Control soil while the lowest concentration (3.14mg/kg) was found in Biochar with dumpsite soil. When subjected to DMRT, there were significant differences in the Pb concentration in the shoot of *A. esculentus* at $p<0.05$ (Appendix E v b). Pb concentration in the shoot of *Amaranthus esculentus* follows this trend: CS >BC > DS > BD.

Pb concentration in the root of *Amaranthus esculentus* has the highest concentration (350.80mg/kg) in the Dumpsite soil with the lowest concentration (22.17mg/kg) found in Biochar with control soil. When subjected to DMRT, there were significant differences in the Pb concentration in the root of *A. esculentus* at P<0.05 (Appendix E vi b). Pb concentration in the root of *A esculentus* followed this trend: DS >BD > CS > BC.

Ni concentration in *Amaranthus esculentus* shoot shows that Ni has the highest concentration (172.2mg/kg) in the Control soil while the lowest concentration (12.26mg/kg) was found in Dumpsite soil. When subjected to DMRT, Ni concentration in *A. esculentus* is significantly different at p<0.05 (Appendix E v c).

Ni concentration in the shoot of *Amaranthus esculentus* followed this trend: CS >BD >BC>DS

Ni concentration in the root of *A. esculentus* has the highest concentration (87.06mg/kg) in the Biochar with dumpsite soil while the lowest concentration (14.47mg/kg) found in Biochar with Control soil. When subjected to DMRT, the Ni concentration were significantly different at p<0.05 (Appendix E vi c).

Ni concentration in the root of *Amaranthus esculentus* followed this trend: BD > CS > DS>BC.

Fe has the highest concentration (1836.22mg/kg) in the shoot of *Amaranthus esculentus* on Control soil while the lowest concentration (496.43mg/kg) was found in Dumpsite soil. When subjected to DMRT, it was found that Fe concentration in the shoot of *A. esculentus* were significantly different at p<0.05 (Appendix E v d.). Fe concentration in the shoot of *Amaranthus esculentus* followed this trend: CS >BC > BD > DS. Fe concentration in the root of *Amaranthus esculentus* has the highest concentration (11635.37mg/kg) in Dumpsite soil while the lowest concentration (1027mg/kg) was found in the Biochar with dumpsite soil. When subjected to

DMRT, there were significant differences in Fe concentration in the root of *A. esculentus* at $p<0.05$ (Appendix E vi d). Fe concentration in the root of *Amaranthus esculentus* followed this trend: DS > CS > BC >BD

Cu has the highest concentration (49.15mg/kg) in the shoot of *Amaranthus esculentus* in the Dumpsite soil while the lowest concentration (30.87mg/kg) was found in the Control soil. When subjected to DMRT, it was found that Cu concentration in the shoot were significantly different at $p<0.05$ (Appendix E v e.). Cu concentration in the shoot of *Amaranthus esculentus* followed this trend: DS >BD >BC>CS

Cu concentration in the root of *Amaranthus esculentus* has the highest concentration (817.94mg/kg) in Dumpsite soil while the lowest concentration (25.75mg/kg) was found in the Biochar with Control soil. When subjected to DMRT, there were significant differences in Cu concentration in the root of *A. esculentus* at $p<0.05$ (Appendix E vi e). Cu concentration in the root of *Amaranthus esculentus* followed this trend: DS >BD > CS >BC.

The highest concentration of Zn (267.99mg/kg) in the shoot of *Amaranthus esculentus* was found in Dumpsite soil while the lowest concentration (130.81mg/kg) was found in the Control soil. When subjected to DMRT, it was found that Zn concentration were significantly different at $p<0.05$ (Appendix E v f.). Zn concentration in the shoot of *A. esculentus* followed this trend: DS> BD >BC > CS.

Zn concentration in the root of *Amaranthus esculentus* has the highest concentration (643.71mg/kg) in Dumpsite soil while the lowest concentration (34.30mg/kg) was found in Biochar with control soil. When subjected to DMRT, there were significant differences in Zn concentration in the root of *A. esculentus* at $p<0.05$ (Appendix E vi f). Zn concentration in the root of *Amaranthus esculentus* followed this trend: DS > BD >CS > BC.

Table 25 also showed the concentration of heavy metals in *Tithonia diversifolia*. Cd has the highest concentration (5.2mg/kg) in the shoot of *T. diversifolia* in the Dumpsite soil while the lowest concentration (0.96mg/kg) was found in Biochar with control soil. When subjected to DMRT, it was found that there were significant differences in the level of Cd concentration in the shoot of *T. diversifolia* at $p<0.05$ (Appendix E vii a).Cd concentration in the shoot of *Tithonia diversifolia* followed this trend: DS >BD > CS>BC

Cd concentration in the root of *Tithonia diversifolia* has the highest concentration (4.49mg/kg) in Dumpsite soil while the lowest concentration (1.7mg/kg) was found in Biochar with control soil. When subjected to DMRT, there were significant differences in the Cd concentration in the root of *T. diversifolia* at $p<0.05$ (Appendix E viii a). Cd concentration in the root of *Tithonia diversifolia* followed this trend: DS > BD > CS > BC.

The concentration of Pb in *Tithonia diversifolia* shoot showed that Pb has the highest concentration (40.38mg/kg) in the Control soil while the lowest concentration (39.28mg/kg) was found in Biochar with dumpsite soil. When subjected to DMRT, there were no significant differences in the Pb concentration in the shoot of *T. diversifolia* at $p<0.05$ (Appendix E vii b). Pb concentration in the shoot of *Tithonia diversifolia* followed this trend: DS =BD = CS = BC. Pb concentration in the root of *Tithonia diversifolia* has the highest concentration (508.92mg/kg) in the Dumpsite soil with the lowest concentration (40.57mg/kg) found in Biochar with control soil. When subjected to DMRT, there were significant differences in the Pb concentration in the root of *T. diversifolia* at $p<0.05$ (Appendix E viii b). Pb concentration in the root of *Tithonia diversifolia* follows this trend: DS >BD > CS > BC.

Ni concentration in *Tithonia diversifolia* shoot showed that Ni has the highest concentration (42.2mg/kg) in the Dumpsite soil while the lowest concentration (8.56mg/kg) was found in the

Control soil. When subjected to DMRT, Ni concentration in *T. diversifolia* were significantly different at $p<0.05$ (Appendix E vii c). Ni concentration in the shoot of *Tithonia diversifolia* followed this trend: DS >BC >BD>CS.

Ni concentration in the root of *Tithonia diversifolia* has the highest concentration (743.79mg/kg) in the Dumpsite soil while the lowest concentration (14.26mg/kg) was found in Biochar with Dumpsite soil. When subjected to DMRT, the Ni concentration were significantly different at $p<0.05$ (Appendix E viii c). Ni concentration in the root of *Tithonia diversifolia* followed this trend: DS > BC > CS>BD.

Fe has the highest concentration (999.9mg/kg) in the shoot of *Tithonia diversifolia* on Dumpsite soil while the lowest concentration (647.5mg/kg) was found in the Control soil. When subjected to DMRT, it was found that Fe concentration in the shoot of *T. diversifolia* were significantly different at $p<0.05$ (Appendix E vii d.). Fe concentration in the shoot of *T. diversifolia* followed this trend: DS >BC > BD > CS.

Fe concentration in the root of *Tithonia diversifolia* has the highest concentration (7002.93mg/kg) in Biochar with control soil while the lowest concentration (3400.43mg/kg) was found in Biochar with dumpsite soil. When subjected to DMRT, there were significant differences in Fe concentration in the root of *T. diversifolia* at $p<0.05$ (Appendix E viii d). Fe concentration in the root of *Tithonia diversifolia* followed this trend: BC > DS > CS >BD

Cu has the highest concentration (34.7mg/kg) in the shoot of *Tithonia diversifolia* in Biochar with dumpsite soil while the lowest concentration (12.6mg/kg) was found in Dumpsite soil. When subjected to DMRT, it was found that Cu concentration in the shoot of *T. diversifolia* were significantly different at $p<0.05$ (Appendix E vii e.). Cu concentration in the shoot of *Tithonia diversifolia* followed this trend: BD >CS >BC>DS.

Cu concentration in the root of *Tithonia diversifolia* has the highest concentration (713.65mg/kg) in Dumpsite soil while the lowest concentration (34.97mg/kg) was found in Biochar with Control soil. When subjected to DMRT, Cu concentration in Dumpsite soil were significantly different from Biochar with dumpsite soil which was significantly different from the Control soil and Biochar with Control soil which were statistically the same at $p<0.05$ (Appendix E vii e). Cu concentration in the root of *Tithonia diversifolia* followed this trend: DS >BD > CS =BC.

The highest concentration of Zn (151.75mg/kg) in the shoot of *Tithonia diversifolia* was found in Dumpsite soil while the lowest concentration (75.37mg/kg) was found in Biochar with Control soil. When subjected to DMRT, it was found that Zn concentration were significantly different at $p<0.05$ (Appendix E vii f.). Zn concentration in the shoot of *T. diversifolia* followed this trend: DS> BD >CS > BC.

Zn concentration in the root of *Tithonia diversifolia* has the highest concentration (1264.87mg/kg) in the Dumpsite soil while the lowest concentration (69.19mg/kg) were in found the Control soil. When subjected to DMRT, there were significant differences in Zn concentration in the root of *T. diversifolia* at $p<0.05$ (Appendix E viii f). Zn concentration in the root of *Tithonia diversifolia* followed this trend: DS > BD >BC > CS.

Table 25 further showed the concentration of heavy metals in *Solanum lycopersicon.* Cd has the highest concentration (3.5mg/kg) in the shoot of *S. lycopersicon* in the Dumpsite soil.Cd concentration in the shoot of *S. lycopersicon* followed this trend: DS >BD. Cd concentration in the root of *Solanum lycopersicon* had the highest concentration (4.7mg/kg) in the Dumpsite soil. Cd concentration in the root of *S. lycopersicon* followed this trend: DS > BD

The concentration of Pb in *Solanum lycopersicon* shoot showed that Pb had the highest concentrations (39.49mg/kg) in the Dumpsite soil. Pb concentration in the shoot of *S. lycopersicon* followed this trend: DS >BD. Pb concentration in the root of *S. lycopersicon* has the highest concentration (613.77mg/kg) in the Dumpsite soil. Pb concentration in the root of *S. lycopersicon* followed this trend: DS >BD

Ni concentration in *Solanum lycopersicon* shoot showed that Ni had the highest concentration (77.5mg/kg) in the Dumpsite soil. Ni concentration in the shoot of *S. lycopersicon* followed this trend: DS >BD. Ni concentration in the root of *Solanum lycopersicon* has the highest concentration (157.3mg/kg) in the Dumpsite soil. Ni concentration in the root of *S. lycopersicon* followed this trend: DS > BD.

Fe has the highest concentration (695.58mg/kg) in the shoot of *Solanum lycopersicon* on Control soil while the lowest concentration (508.18mg/kg) was found in the Dumpsite soil. When subjected to DMRT, it was found that Fe concentration in the shoot of *S. lycopersicon* were significantly different with Biochar with dumpsite soil and Dumpsite soil been statistically the same at $p<0.05$ (Appendix E ix a.). Fe concentration in the shoot of *Solanum lycopersicon* followed this trend: CS >BC > BD = DS.

Fe concentration in the root of *Solanum lycopersicon* has the highest concentration (10248.9mg/kg) in Dumpsite soil while the lowest concentration (495.19mg/kg) was found in Biochar with control soil. When subjected to DMRT, there was significant differences in Fe concentration in the root of *S. lycopersicon* at $p<0.05$ (Appendix E x a). Fe concentration in the root of *Solanum lycopersicon* followed this trend: DS > BD >CS >BC

Cu has the highest concentration (41.16mg/kg) in the shoot of *Solanum lycopersicon* in Dumpsite soil while the lowest concentration (35.1mg/kg) was found in the Control soil. When subjected to DMRT, it was found that Cu concentration in the shoot of *S. lycopersicon* were significantly different with Dumpsite soil and Biochar with dumpsite soil been statistically the same at $p<0.05$ (Appendix E ix b.). Cu concentration in the shoot of *Solanum lycopersicon* followed this trend: DS = BD >BC>CS.

Cu concentration in the root of *Solanum lycopersicon* has the highest concentration (4698.26mg/kg) in Dumpsite soil while the lowest concentration (11.31mg/kg) was found in Biochar with Control soil. When subjected to DMRT, there were no significant differences at $p<0.05$ (Appendix E x b). Cu concentration in the root of *S. lycopersicon* followed this trend: DS >BD > CS =BC.

The highest concentration of Zn (308.57mg/kg) in the shoot of *Solanum lycopersicon* was found in Dumpsite soil while the lowest concentration (8.0mg/kg) was found in Biochar with Control soil. When subjected to DMRT, it was found that Zn concentration were significantly different at $p<0.05$ (Appendix E ix c.). Zn concentration in the shoot of *Solanum lycopersicon* follows this trend: DS> BD >CS > BC. Zn concentration in the root of *Solanum lycopersicon* has the highest concentration (1310.07mg/kg) in the Dumpsite soil while the lowest concentration (22.73mg/kg) was found in Biochar with Control soil. When subjected to DMRT, there were significant differences in the Zn concentration in the root of *S. lycopersicon* at $p<0.05$ (Appendix E x c). Zn concentration in the root of *Solanum lycopersicon* followed this trend: DS > BD >CS > BC.

Table 25 showed the concentration of heavy metals in *Abelmoschus esculentum* fruit. Cd has the highest concentration (2.52mg/kg) in *A. esculentus* fruit in Biochar with dumpsite soil while the lowest concentration (1.65mg/kg) was found on the Control soil. When subjected to DMRT, it

was found there were significant differences in the level of Cd concentration in *A. esculentus* fruit with the fruit from Biochar with Control soil and Control soil were statistically the same at $p<0.05$ (Appendix E xi a.). Cd concentration in *Abelmoschus esculentus* fruit followed this trend:

BD > DS >BC=CS

The concentration of Pb in *Abelmoschus esculentus* fruits showed that Pb has the highest concentration (22.17mg/kg) on the Dumpsite soil while the lowest concentration (0.00mg/kg) was found in Biochar with dumpsite soil and Control, that is Pb was not detected in them. When subjected to DMRT, there were significant differences in the Pb concentration in *A. esculentus* fruit while the fruit from Biochar with dumpsite soil and Control soil were statistically the same at $p<0.05$ (Appendix E xi b). Pb concentration in *A. esculentus* fruit followed this trend: DS >BC >BD = CS.

Ni concentration in *Abelmoschus esculentus* fruits showed that Ni has the highest concentration (15.27mg/kg) in the fruit from Control soil while the lowest concentration (11.08mg/kg) was found in the fruit from Biochar with dumpsite soil. When subjected to DMRT, Ni concentration in *A. esculentus* fruit were significantly different from Biochar with Control soil and Dumpsite soil been statistically the same at $p<0.05$ (Appendix E xi c). Ni concentration in *Abelmoschus esculentus* fruit followed this trend: CS >BC =DS>BD.

Fe has the highest concentration (338.83mg /kg) in *Abelmoschus esculentus* fruit on Dumpsite soil while the lowest concentration (220.69mg/kg) was found in the Control soil. When subjected to DMRT, it was found that Fe concentration in *A. esculentus* fruit were significantly different with the fruit from Biochar with dumpsite soil and Control soil been statistically the same at

$p<0.05$ (Appendix E ix d.). Fe concentration in *Abelmoschus esculentus* fruit followed this trend: DS >BC > BD = CS

Cu has the highest concentration (18.43mg/kg) in *Abelmoschus esculentus* fruit in Dumpsite soil while the lowest concentration (10.83mg/kg) was found in Biochar with control soil. When subjected to DMRT, it was found that Cu concentration in *A. esculentus* fruit were significantly different at $p<0.05$ (Appendix E xi e.). Cu concentration in *A. esculentus* fruit followed this trend: DS >CS >BD>BC

The highest concentration of Zn (110.20mg/kg) in *Abelmoschus esculentus* fruit was found in the Control soil while the lowest concentration (70.1mg/kg) was found in Dumpsite soil. When subjected to DMRT, it was found that Zn concentration were significantly different at $p<0.05$ (Appendix E xi f.). Zn concentration in *Abelmoschus esculentus* fruit follows this trend:
CS> BC >BD > DS.

Table 26 shows the transfer factor of the test plants. *Abelmoschus esculentum* on the dumpsite soil accumulated Ni and Zn, but Cu, Pb and Fe were excluded while Cd was moderately accumulated. *A. esculentum* on Biochar with dumpsite soil were excluders with Cd and Ni being moderately accumulated while Pb, Fe and Cu been excluded from the Control soil. *A. esculentum* on Bichar with control soil also accumulated Cu with Pb, Ni and Zn been moderately accumulated and Fe being excluded. *Corchorus olitorious* accumulated Cd and Pb in the Control soil and Dumpsite soil, respectively while the other treatments excluded all the heavy metals under study. *Amaranthus esculentus* accumumlated Cd on Dumpsite soil and Control soil while Cd was moderately accumulated on Biochar with dumpsite soil and Biochar with control soil. Pb was accumulated in *A. esculentus* on Control soil and Biochar with control soil while it was

excluded by *A. esculentus* on Dumpsite soil and Biochar with dumpsite soil. Ni was accumulated in *A. esculentus* on Control soil but was moderately accumulated in Dumpsite soil and Biochar with control soil but it was excluded in *A.esculentus* on Biochar with dumpsite soil.

Fe was moderately accumulated in *A. esculentus* in Biochar with dumpsite soil and excluded in the other treatments. Cu was accumulated in Biochar with Control soil, moderately accumulated in Control soil and excluded in Dumpsite soil and Biochar with dumpsite soil. Zn was highly accumulated by *Tithonia diversifolia* in all the treatments with the exception of Dumpsite soil where it was excluded. Cd was highly accumulated in Dumpsite soil, Biochar with dumpsite soil, Control soil but moderately accumulated in Biochar with control soil. Pb was moderately accumulated in Control soil and Biochar with control soil while it was excluded in dumpsite soil and Biochar with dumpsite soil. Ni was accumulated by *T.diversifolia* in Biochar with dumpsite soil and Biochar with control soil while it was exluded in Dumpsite soil and Control soil. Fe and Cu were excluded by *T. diversifolia* in all the treatments. Cu was excluded in all the treatments with the exception of Control soil where it was moderately accumulated. Zn was highly accumulated in the Control soil, moderately accumulated in Biochar with dumpsite soil and Biochar with control soil but excluded in *T. diversifolia* on Dumpsite soil.

In *Solanum lycopersicon* Cd was moderately accumulated while Pb was excluded in all treatments. Ni wsa moderately accumulated in Biochar with dumpsite soil and excluded in Dumpsite soil. Fe was highly accumulated in Biochar with control soil, moderately accumulated in Control soil and excluded in Dumpsite soil and Biochar with dumpsite soil by *S. lycopersicon*. Cu was highly accumulated in Biochar with control soil but excluded in other treatments by *S. lycopersicon.*Zn was also excluded in all treatments with the exception of Control soil where it was moderately accumulated.

Table 26. Transfer Factor of test plants in different soils

Crops/ Heavy Metal	Treatments	Cd	Pb	Ni	Fe	Cu	Zn
Abelmoschus esculentum	DS	0.9**	0.05**	1.01*	0.23**	0.03**	3.02*
	BD	0.95**	0.12**	0.62**	0.09**	0.06**	0.31**
	CS	0.73**	0.49**	0.57**	0.31**	0.41**	1.00*
	BC	0.48**	0.56**	0.93**	0.07**	5.89*	0.82**
Corchorus olitorious	DS	0.46**	1.00*	0.23**	0.03**	0.01**	0.19**
	BD	0.28**	0.188*	0.00**	0.01**	0.01**	0.09**
	CS	1.01*	0.008*	0.28**	0.02**	0.21**	0.43**
	BC	0.69**	0.16**	0.00**	0.02**	0.17**	0.37**
Amaranthus esculentum	DS	1.98*	0.05**	0.69**	0.04**	0.06**	0.42**
	BD	0.78**	0.03**	0.46**	0.81**	0.33**	1.35*
	CS	2.51*	1.01*	2.70*	0.288*	0.98**	2.13*
	BC	0.96**	1.25*	0.93**	0.15**	1.28*	3.91*
Tithonia diversifolia	DS	1.16*	0.08**	0.06**	0.15**	0.02**	0.12**
	BD	1.06*	0.29**	1.70*	0.21**	0.17**	0.55**
	CS	1.00*	0.81**	0.37**	0.13**	0.52**	1.44*
	BC	0.56**	0.98**	1.32*	0.11**	0.48**	0.82**
Solanum lycopersicon	DS	0.75**	0.06**	0.49**	0.05**	0.01**	0.24**
	BD	0.53**	0.07**	0.64**	0.07**	0.04**	0.25**
	CS	-	-	-	0.79**	0.03**	0.62**
	BC	-	-	-	1.22*	3.44*	0.35**

DS - Dumpsite Soil
BD – Biochar with Dumpsite soil
CS – Control Soil
BC – Biochar with Control soil
* - Accumulators
** - Excluders

Table 27 shows the Biological Accumulation Coefficient (BAC) which is the ratio of heavy metals in shoot to that in the soil (Liu *et al.,* 2007). *Abelmoschus esculentum* and *Corchorus olitorious* are excluders of the studied heavy metals. *Amaranthus esculentus* and *Solanum lycopersicon* are accumulators of Ni in their shoots and excluders of the other metals under study. *Tithonia diversifolia* also is an accumulator of Cd and Ni in its shoot but excluder of the other heavy metals under study These results suggested that Ni and Cd has greater accumulation ability in shoots of these plants than the other heavy metals studied.

Table 27. Biological Accumulation Coefficient (SOIL-SHOOT)

	Shoot	Cd	Pb	Ni	Fe	Cu	Zn
Abelmoschus esculentum	DS	0.78	0.03	0.60	0.06	0.03	0.22
	BD	0.66	0.02	0.38	0.02	0.02	0.22
	CS	0.23	0.02	0.65	0.05	0.02	0.14
	BC	0.24	0.02	0.38	0.03	0.02	0.22
Corchorus olitorious	DS	0.60	0.07	0.19	0.02	0.02	0.19
	BD	0.25	0.01	0.00	0.01	0.01	0.06
	CS	0.25	0.00	0.27	0.01	0.01	0.06
	BC	0.26	0.01	0.00	0.01	0.01	0.07
Amaranthus esculentus	DS	0.64	0.02	0.64	0.03	0.05	0.33
	BD	0.66	0.00	2.12	0.05	0.04	0.30
	CS	0.67	0.05	9.06	0.10	0.03	0.16
	BC	0.63	0.37	0.71	0.05	0.03	0.17
Tithonia diversifolia	DS	1.45	0.05	2.22	0.06	0.01	0.19
	BD	1.02	0.05	1.28	0.04	0.04	0.18
	CS	0.65	0.05	0.45	0.04	0.02	0.12
	BC	0.27	0.05	1.67	0.04	0.02	0.09
Solanum lycopersicon	DS	0.99	0.05	4.07	0.03	0.04	0.38
	BD	0.68	0.03	0.79	0.03	0.04	0.36
	CS	ND	ND	ND	0.04	0.04	0.10
	BC	ND	ND	ND	0.03	0.04	0.01

DS - Dumpsite Soil
BD – Biochar with Dumpsite soil
CS – Control Soil

BC – Biochar with Control soil
ND- Not Detected

Table 28 shows the Biological Concentration Factor (BAC) which is the ratio of metal concentration in the root to the equivalent concentration in the soil (Ginicchio and Baker, 2004). Ni was accumulated in the root of *Abelmoschus esculentum* and *Amaranthus esculentus* while the other metals under study were excluded. Cd, Ni and C accumulated in the root of *Corchorus olitorious* while Pb, Fe and Zn were excluded. In *Tithonia diversifolia*, Cd, Ni and Zn were accumulated in the root while Pb, Fe and Cu were excluded. *Solanum lycopersicon* acted as an accumulator of Cd, Ni, Cu and Zn in its roots and excluder of Pb and Fe. With these, all the plants used in this acted as excluders to Pb and Fe.

Table 28. Biological Concentration Factor (SOIL - ROOT)

Plants	Treatment	Cd	Pb	Ni	Fe	Cu	Zn
Abelmoschus esculentum	DS	0.86	0.66	0.60	0.24	0.85	0.07
	BD	0.70	0.18	0.61	0.25	0.31	0.72
	CS	0.32	0.04	1.14	0.17	0.05	0.14
	BC	0.50	0.04	0.41	0.37	0.00	0.28
Corchorus olitorious	DS	1.35	0.07	0.82	0.55	1.70	0.97
	BD	0.90	0.04	1.14	0.45	0.53	0.74
	CS	0.25	0.04	0.95	0.54	0.07	0.15
	BC	0.38	0.04	0.65	0.61	0.04	0.19
Amaranthus esculentum	DS	0.32	0.46	1.10	0.64	0.85	0.80
	BD	0.85	0.13	4.58	0.06	0.11	0.23
	CS	0.27	0.05	3.35	0.37	0.03	0.08
	BC	0.65	0.03	0.76	0.35	0.03	0.04
Tithonia diversifolia	DS	1.26	0.67	3.11	0.37	0.74	1.58
	BD	0.97	0.18	0.75	0.19	0.21	0.33
	CS	0.66	0.07	1.22	0.27	0.04	0.09
	BC	0.47	0.05	1.25	0.39	0.04	0.11
Solanum lycopersicon	DS	1.32	0.81	8.27	0.57	4.87	1.63
	BD	1.28	0.44	1.22	0.40	1.08	1.44
	CS	ND	ND	ND	0.05	1.07	0.16
	BC	0.65	0.01	0.75	0.03	0.01	0.03

DS - Dumpsite Soil
BD – Biochar with Dumpsite soil
CS – Control Soil

BC – Biochar with Control soil
ND- Not Detected

The Hazard Quotient (HQ) was calculated for the crops grown in this experiment. Table 29 shows the HQ of the plants. The HQ for all the heavy metals under study showed adverse health risk as most of the HQ values were greater / equal to 1. The HQ for Cd in all the plants under study indicated potential health risk to consumers in Kwara state, as the recommended safe limit for HQ is 1. Moreover, the HQ for Pb in all the plants under study indicated potential health risk with the exception of the shoot of *Corchorus olitorious* in the Control soil and *Abelmoschus esculentum* fruits on Biochar with dumpsite soil and Control soil that were less than 1. That is, there was no potential health risk on the consumers, while other plants in other treatments were far greater than 1. Which means consumers of these will be proned to potential health risk. The HQ for Ni in all the plants under study indicated potential health risk with the exception of *Abelmoschus esculentum* on Biochar with dumpsite soil (shoot), Biochar with control soil (shoot and root), *Corchorus olitorious* (shoot) and *Tithonia diversifolia* (shoot) on the Control soil had their HQ less than 1 at which means there would be no significant health hazards.

Furthermore, the HQ for Fe in all the plants under study indicated potential health risk with the exception of *C. olitorious* (shoot) in Biochar with dumpsite soil, Control soil and Biochar with control soil with *Abelmoschus esculentum* fruits on Biochar with dumpsite soil, Control soil and Biochar with control soil which had their HQ less than 1. That is, no potential health risk on the consumers. HQ for Cu in all the plants under study indicated potential health risk to consumers with the exception of *Abelmoschus esculentum* (root) on Biochar with control soil; Biochar with dumpsite soil, Control soil and Biochar with control soil (shoot) in *C. olitorious,* shoots in Dumpsite soil and Biochar with control soil in *Tithonia diversifolia,* the root of Biochar with control soil in *Solanum lycopersicon* and *Abelmoschus esculentum* fruits that had no potential health risk on the consumers because their HQ was less than 1.

Also, the HQ for Zn in all the plants under study had their HQ greater than 1 that is, there is a potential health risk to consumers with the exception of *A. esculentum* (shoot) in the Control soil, Dumpsite soil and Control soil (root), *C. olitorious* (shoot) and Control soil root, *Amaranthus esculentus* shoot and roots in Control soil and Biochar with control soil, *T. diversifolia* shoot and roots in Control soil and Biochar with control soil, *Solanum lycopersicon* shoot and roots in Control soil and Biochar with control soil and *A. esculentum* fruits will have no potential health risk on the consumers because their HQ was less than 1. The greater the HQ is than 1, the greater the level of concern since the acceptable value is 1, at which there would be no significant health hazards (Grzetic and Ghariani, 2008)

Accuracy and precision of this work were compared to results of the standard reference materials from International Atomic Energy Agency IAEA-SL-1 Lake Sediment and Cabbage IAEA-359 used for the accuracy in heavy metal levels in the soil and plant samples. The Standard Reference Material (SRM) results obtained are shown in Tables 29 of the plant samples. The recoveries obtained for Pb, Ni, Fe, Cd and Zn in the plants when compared with Cabbage IAEA-359 were below 70% and Cd, Ni and Pb in IAEA-SL-1 Lake Sediment for soil samples. All others were in good accord with the certified values that is above 70%.

TABLE 29. Percentage recovery (%) of metals in reference materials used to ascertain quality control.

	IAEA- SL-1(lake sediment)			IAEA – Cabbage-359		
	Mean value (Study)	Mean value (Certified)	% Recovery	Mean value (Study)	Mean value (Certified)	% recovery
Cd	4.12	4.6	111.6%	4.42	0.12	2.7%
Pb	54 .8	37.7	68.8%	NA	NS	
Ni	96.4	44.9	46.6%	43.3	1.05	2.4%
Fe	50367.5	67400	133.8%	344.12	148	43%
Cu	28.2	30	106%	6.58	5.67	86.1%
Zn	283.92	223	78.5%	139.8	38.6	27.6%

NS-NOT SPECIFIED

Elemental analysis of maize-cob biochar

The percentages of the element in the maize cob-derived biochar are displayed in Table 30. CHN analysis is a form of elemental analysis for determination of only carbon, hydrogen and nitrogen present in a sample (Shaaban *et al.,* 2013). The carbon content of maize cob-derived biochar was recorded as 42.97%, which is comparable to those of the literature results (Chaisarn *et al.,* (2008); Srinisvasakanan *et al.,* 2004). High carbon content in maize cob-derived biochar is an indication of higher purity of the biochars.

Table 30. Elemental analysis CHN in maize cob-derived biochar

Element	Ultimate analysis (%)		
	Current work	Srinisvasakanan *et al.,* (2004)	Chaisarn *et al.,*(2008)
Carbon	42.97	43.98	44.03
Hydrogen	6.83	8.04	7.99
Nitrogen	0.39	0.00	0.00

Fig. 2 illustrates the SEM micrographs of maize cob-derived biochar. The surface of maize cob-derived biochar are shown in Fig. 2. The biochar has many well-defined pores which might be caused by volatilization of organic compounds. Based on the outward appearance, it could be said that the pores are not cross-linked and it was observed that the pore sizes were relatively smaller with higher pore volume. Increased porosity from volatiles of the organic compound escaping during thermochemical degradation can also be seen. Scanning electron micrographs (SEM) images are very useful to obtain accurate details about surface structure of biochar. The comparison of the images between biochar and their raw feedstock might help in knowing the morphological changes during the carbonization stage (Ozcimen and Ersoy–Mericboyu, 2010).

The SEM pictures of biochar produced at 600˚C was given in Fig. 2. The surfaces of maize cob-derived biochar was imaged with many hollow channels in diameters of around 10 to 20 micrometers. These porous structures of the biochar is likely to provide a high internal surface area, adsorption ability for soluble organic matter and inorganic nutrients, and suitable habitat for microbes such as bacteria and arbuscular mycorrhizal fungi.

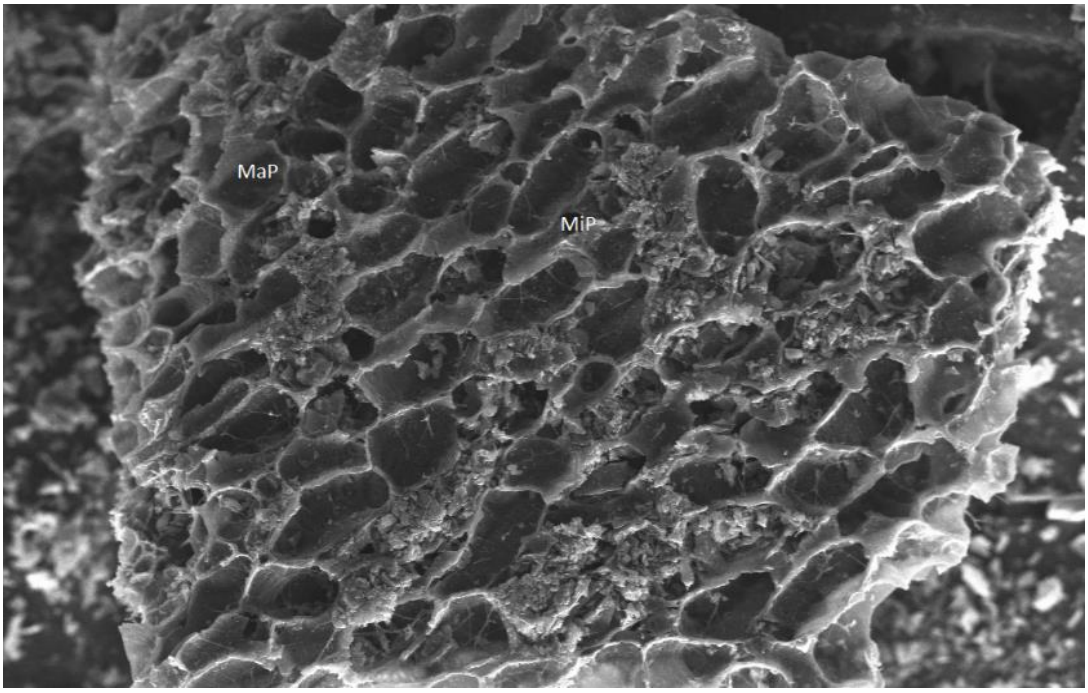


Fig 3: SEM micrograph showing the macropore and the micropore

MaP: Macropore

MiP: Micropore

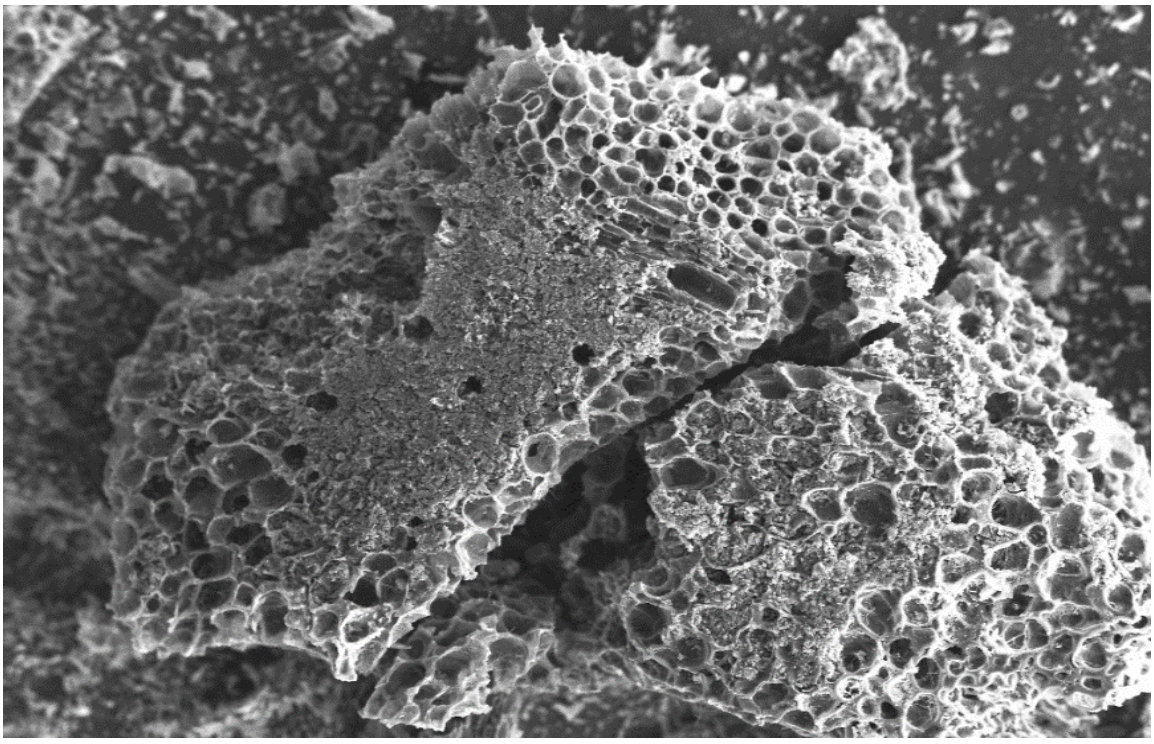


Fig 4. SEM micrograph of maize cob-derived biochar that shows the carbonaceous skeleton; meso and micro pore of carbon

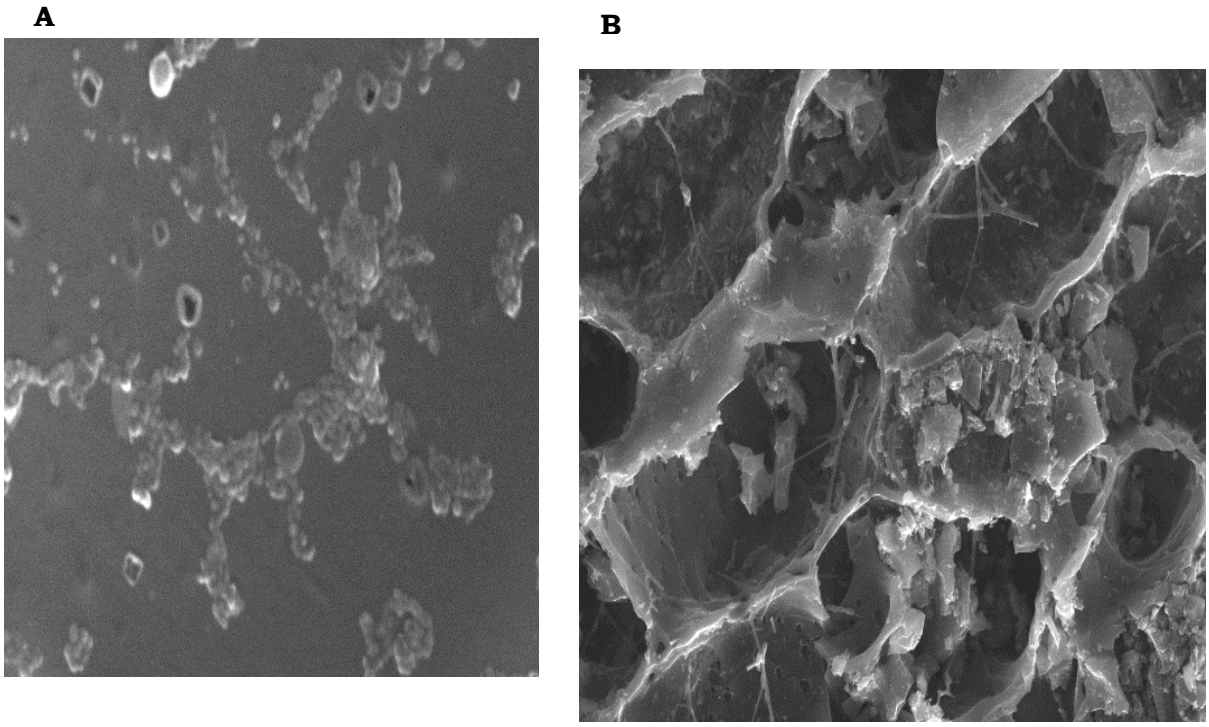


Fig. 5. SEM micrograph showing the external surface of (a) typical agglomerate and (b) quadrate sample of a maize cob derived biochar

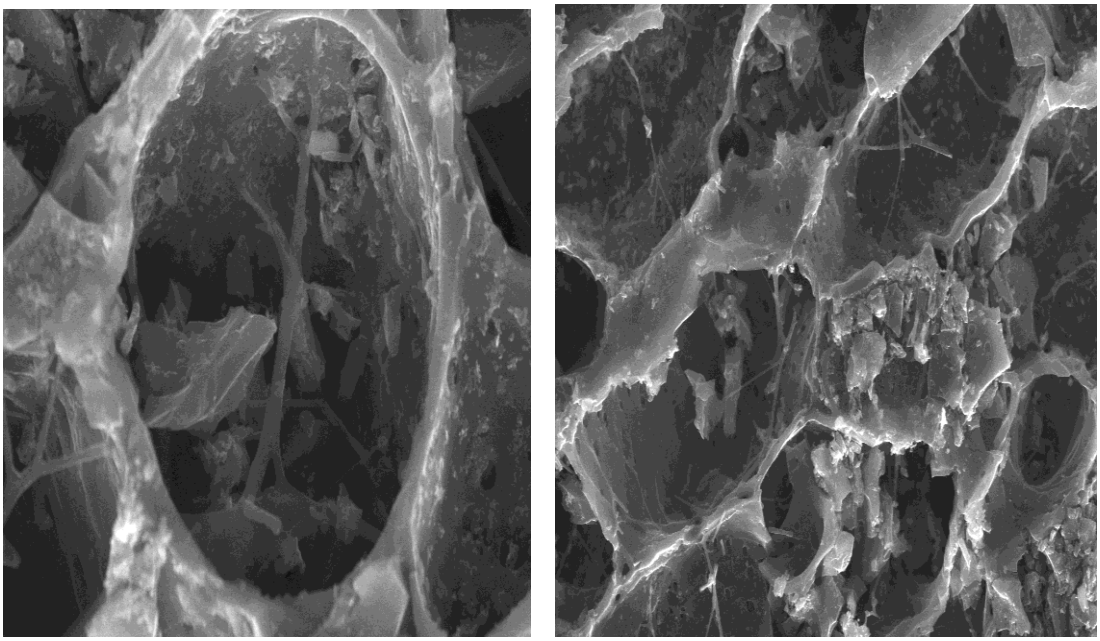


Fig 6. SEM micrograph of maize cob-derived biochar showing its porosity

Spectra of EDX analysis are shown in Fig. 6. The peak intensity in EDX analysis is not a quantitative measure of the concentration of the element in the sample but relative concentration can be inferred from the relative peak height. Figure 4, shows some quadrate crystal phases. The EDX analysis in Table 26 shows that the constituents of the biochar were Carbon, Oxygen, Magnesium, Silica and Potassium. This result is consistent with Yao *et al.*, (2016), where the author observed *the* presence of Si and O in a quadrate structure from SEM micrograph. Park *et al*. (2003) stated that SiO_2 is in the amorphous state under 800^0C but when the temperature exceeds 900^0C, the SiO_2 having a microcrystalline structure is transformed into a crystalline from the amorphous state. The high percentage of carbon was observed in Table 26, this value is good to produce high amount of energy. (Noor *et al.*, 2012).

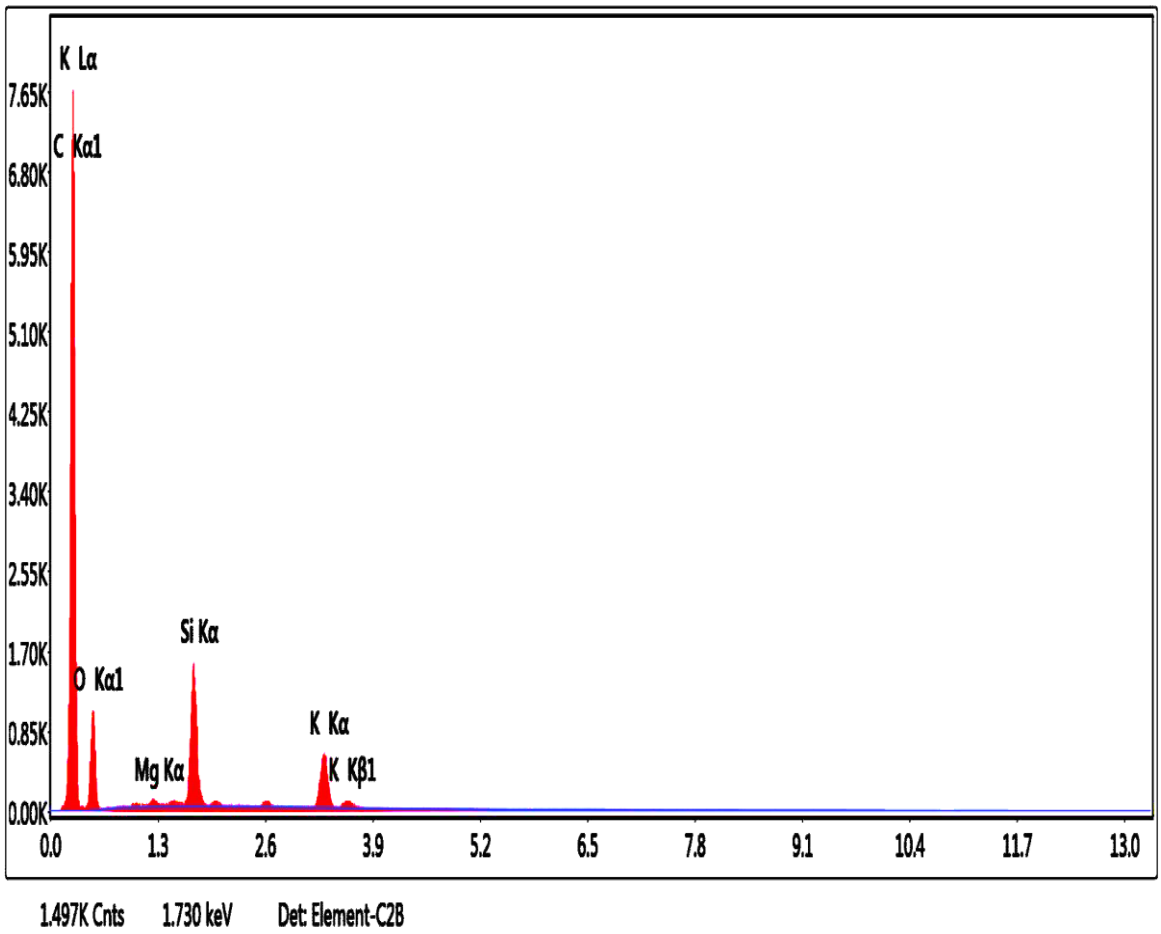


Fig 7. EDX of the maize cob-derived Biochar

Table 31. Percentage of localized carbon, oxygen and some minerals content by SEM-EDX analysis of the biochar (wt %).

Element	Weight (%)	Atomic mass (%)
Carbon	69.13	78.00
Oxygen	20.91	17.71
Magnesium	0.56	0.31
Silica	5.27	2.54
Potassium	4.13	1.43

Fourier Transform Infrared Spectroscopy (FT-IR) is normally used to identify and qualitatively track changes in functional groups in biochar and soil samples. Since biochars are opaque solids, an FT-IR analysis requires special sample preparation. Some common methods include conventional transmission FT-IR using potassium bromide (KBr) pressed pellets, The results of the FT-IR analysis of the Maize Cob-derived Biochar (MCB) are presented in Figure 7 showing the functional groups of the biochar. The MCB showed peaks at 2363cm^{-1} corresponding to C≡C stretching alkyne group and a peak at 1992cm^{-1} corresponding to C-H compound. The feedstock spectrum is dominated by the O-H stretch, aliphatic C-H stretch and carboxyl C=O stretch. As the pyrolysis reaction progresses, certain peaks (O-H stretch and carboxyl C=O stretch) disappeared and the C-H peaks shift from being more aliphatic to being more aromatic.

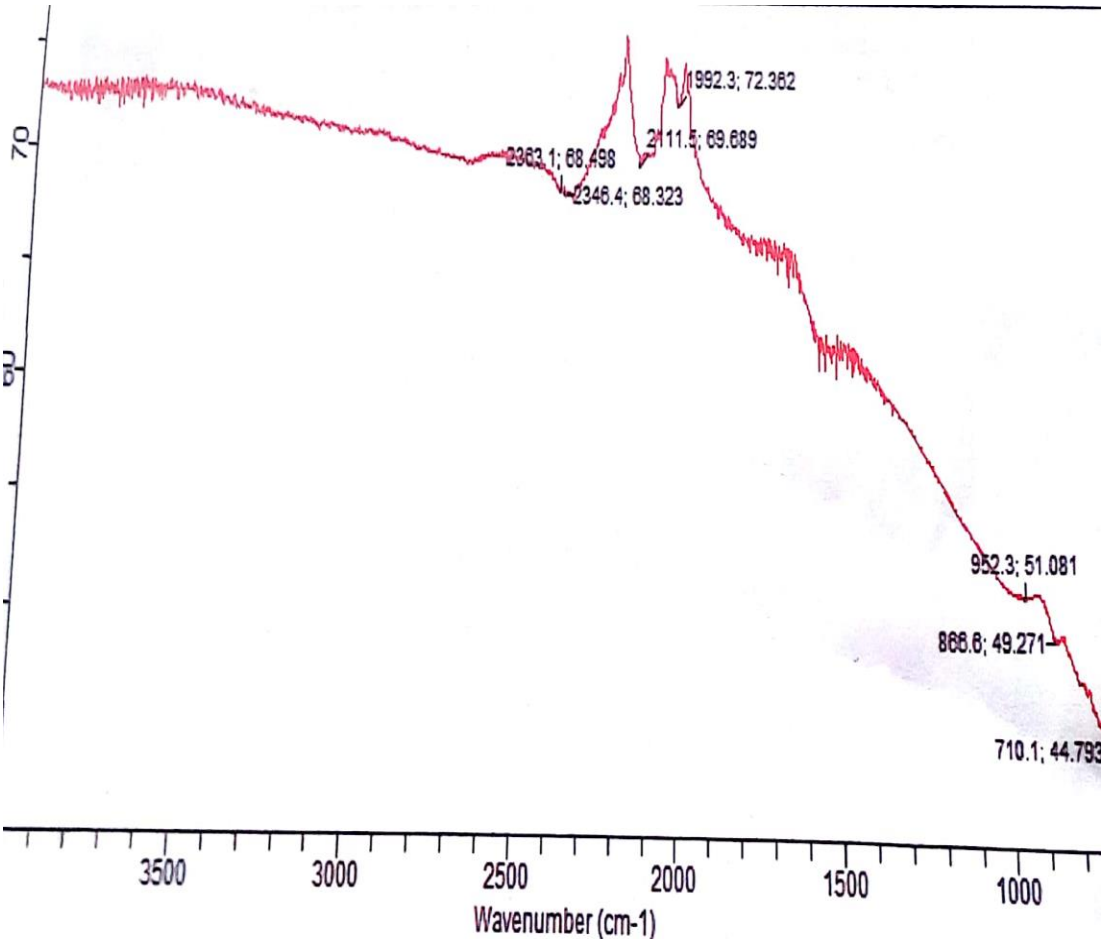


Fig. 8. FT-IR spectra for maize cob-derived biochar

CHAPTER 5

DISCUSSION

The top layer (0-15cm) soils used in this research work was in line with Robson *et al.* (1997) who reported that the top soil layer is a better indicator of metallic burden. Moreover, environmental conditions bind and hold the soil together thereby retaining the water soluble metal in the top soil (Turer *et al*., 2001). Likewise, it is in this region that plant roots are mainly found (Gracia and Millan, 1998), suggesting that the top soil is the reservoir of nutrients.

The concentration of heavy metals in the soil and plant samples from the dumpsites were higher than the Control. Aran-Orin, Offa and Omu-Aran dumpsites were found to be more contaminated/ polluted than other dumpsites. These highly polluted areas are both urban and rural dumpsites. It was observed that irrespective of the location of the dumpsites, the presence of batteries, cans, polyethylene bags, bottles and other metals contributed to the high concentrations of heavy metals present. It can be concluded that the presence of these wastes in these dumpsites could be the major reason for the high concentrations of heavy metals than the Control.

The difference in the heavy metal concentrations of the dumpsites when compared with the Control can be attributed to differences in the type of wastes, quantity of wastes and age of soil. This suggests that the metal contents of the soil can be traced to different substances dumped at each dumpsite locations. It has been found that Fe concentration was exceptionally high. This agreed with the observations reported on Bode-Osier dumpsite and Obafemi Awolowo University Central refuse dump, (Amusan *et al.,* 2005).

In nature, lead is an ubiquitous but biologically non-essential elements (Ewers and Schlipkoter, 1991). However, during the last fifty years, the use of lead in batteries, cable coverings, gasoline additives, explosives and ammunitions as well as in the manufacture of pesticides and analytical reagents have caused a wide spread of environmental contamination (Ewers and Schlipkoter, 1991; Johnson, 1998). Lead has the highest concentration in Oko-Olowo at 10 meters away from the center of the dumpsites. The mean concentration of Pb in the soil samples collected from all the dumpsites ranged from 0.5-75.0mgkg^{-1}. This concentration range is higher than the European Commission (EC) upper permissible limit of 0.3mg/kg. The values obtained for Pb were within the allowable limit for Pb in several countries (Table 32). The concentration of Pb in all the dumpsites were high with the exception of Ipee at 20 meters and Offa at 40 meters where it was not detected. The concentration of Lead in all the dumpsites were higher than those obtained from the Control sites which implies that the decomposition of waste at the dumpsites might have introduced Lead into the soil. This study agrees with (Aluko *et al.,* 2003) who reported that the mean concentration of Lead in the soil at Ibadan dumpsite was high.

The pollution of soil by Lead is a very serious problem that has been given much attention by the environmentalists. This is due to the fact that Lead is an accumulative pollutant (Dara, 1993). Moreover, the mean concentration of Lead in the soil from the dumpsites were lower than the threshold and world mean values of 100mg/kg and 27mg/kg, respectively for uncontaminated soils, as reported by European Commission (2006) and Kabata-Pendias (2011), respectively. The mean Pb contents were also below the target value of 85.0mg/kg stipulated by Department of Petroleum Resources (1991) for Nigerian soils. The concentration of Pb in all the dumpsites were lower compared to the results obtained in three dumpsites soil analyzed by Anikwe and Nwobodo (2002) (423.00±4.90, 437.50± 5.20 and 430.30±4.10 mg/kg). Pb was observed to have

the highest concentration in Oko-Olowo at 10meters and 40meters away from the core of the dumpsite, 75.0mg/kg and 42.0mg/kg, respectively.

The high concentration could also have its source from automobile exhaust fumes as well as dry cell batteries, sewage effluent, run-off of wastes and atmospheric deposition which could cause its bioaccumulation in plants through uptake from the soil and its eventual entry into the food chain (Opaluwa *et al*., 2012). The concentration of Pb was also lower than EU upper limit of 300mg/kg (EC, 1986) and was within the maximum tolerable levels proposed for agricultural soil, 0-300mg/kg (Kabata-Pendias, 1991). The values obtained for Pb were also below the allowable limit of Pb in some countries like Austria and France but were far above the allowable limit for Pb in soils for France, Denmark, Netherland, Sweden and Spain (Table 32). The concentration of Pb in the dumpsite soil in relation to its concentration in the Control soil (1.5mg/kg and 0.5mg/kg) indicates that the dumpsite contributed a considerable amount of Pb to the soil and the environment. This may be due to the fact that the dumpsites is located closely to an automobile and auto body repair workshop.

Table 32 – Allowable limits of heavy metal concentration in soils (mg/kg)

Heavy metal	Austria	Germany	France	Denmark	Netherland	Sweden	Spain
Cd	1-2	1	2	0.5	0.5	0.4	1
Cr	100	60	150	30	30	60	100
Co	50	-	-	-	-	-	-
Ni	50-70	50	50	15	15	30	30
Pb	100	70	100	40	40	40	50

SOURCE: ECDGE (2004) *www.Iosrjournals.Org*

Iron has the highest concentration among all the heavy metals analyzed in all the dumpsites (1,390 mg/kg – 20,850 mg/kg) which suggests that all the dumpsites are enriched with Fe through metal deposition. Besides Fe has been reported to be the most abundant mineral in the Nigerian soil (Amusan *et al*., 2005). This research work agrees with the result of the study. Fe concentration in the Control soil was 2,850 mg/kg - 3,550 mg/kg. The Fe content obtained in this study was higher than 289.30 – 360.09 mg/kg reported in the dumpsite soil by Odukoya *et al*. (2000). The concentration of Fe in all the dumpsite soils were higher than 200.01 – 655.90 mg/kg reported in a dumpsite by Oluyemi *et al*.(2013) during the study of the uptake of heavy metals by tomato (*Lycopersicon esculentus*) grown on soil collected from the dumpsites in Ekiti

State, South West Nigeria.

The values obtained for Fe in this research work were far above the result gotten for Fe by Opaluwa *et al*. (2012), 0.63 mg/kg in Lafia metropolis. It has also been confirmed that natural soils contain significant concentration of Iron (Ademoroti, 1996; Aluko *et al*., 2003; Dara, 1993; Eddy, 2004). Eddy *et al*. (2005) suggested that the pollution of the environment by Iron cannot be conclusively linked to waste materials alone but other natural sources of Iron must be taken into consideration. The high concentration of Fe in all the dumpsites under study was in agreement with Soladoye *et al*. (2015) who also worked on dumpsite soil in Ilorin metropolis. The high concentration of Iron can be due to anthropogenic activities such as disposal of structural components of building materials, condemned automobile parts which are made up of Iron into the dumpsites (Soladoye *et al*., 2015). The concentration of Iron in this study fell within the range of soil proposed by Radojevic and Bashkin (2006).

This study showed that the soil from the dumpsites are contaminated with high concentration of Copper. Copper is a naturally occurring in the soil but its concentration can be greatly increased by anthropogenic activities. Copper is an essential micronutrients to organisms but at higher concentrations, it is toxic (Markert *et al*., 1996). Copper is derived from engine wears, thrust bearing and bearing metals which were common in some of these dumpsites. The Cu concentration of the soil from the dumpsites ranged from 0.5 – 225 mg/kg. Cu content in the soil differed according to the soil types and pollution sources (Wang *et al*., 2006). Some studies have shown different values for Cu contents in the soil such as 0.0014 – 0.0038 mg/l (Madejon, 2002) and 0.06 – 0.73 mg/l (Shallari, 1992). Normal Cu contents of soils range from 0.02 -0.1mg/l (WHO, 1984). Cu contents of the analysed soil samples were high in most of the dumpsites than the Cu content of the Control soil with the exception of Odo-Ore at 20meters and Offa at

40meters which had 0.5±0.1 mg/kg and 1.5±0.2 mg/kg, respectively while the Control sites had 2.5±0.1 mg/kg. The highest concentration of Cu (225.0mg/kg) found in Oko-Olowo dumpsite at 10meters away from the core of the dumpsite could be as a result of engine parts that were dumped there.

Cu concentration greater than 0.4mg/l of dry matter can induce toxicity in plants and cause toxic effects in animals e.g. sheep feeding on them (Davis *et al*., 2003). Therefore, the plants on these dumpsites are potential poison to man and animals because the Cu concentration was more than the permissible limit of 0.1mg/l. The values obtained for Cu in this study is higher than 0.91mg/l obtained by Opaluwa *et ai*. (2012) but the Cu concentration in Odo-Ore at 20meters fell below the result gotten by Opaluwa *et al*. (2012). The result of the study agrees with that of Oluyemi *et al*.(2013) that reported Cu concentration to be between 66.67 – 107.00 mg/kg, with the exception of Oko-Olowo at 10meters that exceeded this. The observation from this study bears a resemblance with the normal range of concentration of heavy metals in soils observed by Alloway (1996); Radojevic and Bashkin, (2006).

The mean concentrations of Cu in the studied sites were generally below 38.9mg/kg, World unpolluted soil average reported by Kabata-Pendias (2011) with the exception of Ipee at 0meters, Oko-Olowo and Offa dumpsites which at 10meters, were above the World unpolluted soil average. The Cu concentration in all the dumpsites with the exception of Oko-Olowo at 10meters were below the threshold level of 100 mg/kg proposed by European Union Commission Regulation, (2006). Likewise, the Cu content in the studied dumpsites was over 50 % less than the target and intervention values of 36.0 mg/kg and 190.0 mg/kg (DPR, 1991). Herselman *et al*. (2005) reported the range of Cu in soils of South Africa to be between 3-117 mg/kg with an established maximum tolerable level (MTL) value of 100 mg/kg.

The Cadmium concentration of soil samples from the dumpsites ranged from 0.50-4.0mg/kg, thus indicating the pollution of some of the dumpsites with Cd. Cd was not detected in Offa, Odo-Ore and Aran-Orin at the centre of the dumpsites (0meters), Offa at 20meters, Oko-Olowo and Ipee at 30meters and Omu-Aran at 40meters. The source of Cd is much less defined than that of Pb, However, metal plating, tyre wears and tears are considered likely sources of Cadmium (Soler and Soler, 1996). Cd is also an additives of Cd lubricating oil. Of all the dumpsites studied, Ipee has the highest concentration of Cd as this may be attributed to the fact that the dumpsite is situated close to a motor mechanic and vulcanizing workshop. Oko-Olowo also had a relatively high concentration of Cd this may be as a result of the dumpsite located close to a major road in Ilorin metropolis. It was reported by Awofolu (2005) that the Cd level in car tyres ranged from 0.02 – 0.09mg/kg. Ward *et al.* (1975) indicated vulcanization as a source of Cd to the environment. Also, Cd as additives present in lubricating oil as well as about 20 - 90µg/g of Cd has been reported in car tyres so they are released into the environment during vulcanization process (Jaradat and Momani, 1999).

In the absence of any major industry in the vicinity of the dumpsites under study, the elevated Cd level in some of the dumpsites compared to the Control sites could be due to lubricating oils, wearing off and tearing of tyres caused by the abrasion on rough surfaces of the road. Most of the dumpsites under study were located either close to a vulcanizing workshop, automobile workshop or close to the road. Values of Cd were within the allowable limits for Cd in some countries with the exception of Ipee at 40 meters that was above the allowable limit (Table 32). Ipee had the highest mean concentration of Cd in all the dumpsites which may be attributed to the disposal of condemned automobile parts, automobile batteries and car tyres and it has been reported that batteries are good sources of several heavy metals which include Pb, Cd

and Cr when present in the soil poses a great health risk even in low concentrations (Yufang *et al*., 2014). The activities of scavengers are reduced because its in a rural environment and the means of transportation from the place may be difficult. The Cd concentration observed in this study was below the result gotten by Awokunmi *et al*.(2010) who reported a higher cadmium level of 219-330 mg/kg at the surface layer of the dumpsite and more at 200meters away. The world average Cd concentration in the soil is estimated at 0.4mg/kg (Kabata-Pendias, 2011). The values obtained in this study was lower than the guideline value of 3.0mg/kg stipulated by European Union (E.U.C.R. 2006) and the 17mg/kg intervention value specified for Nigeria soil (D.P.R. 1991). The concentration of Cd in the dumpsites with the exception of Ipee at 40meters fell within the normal range for soil proposed by (Alloway 1996) and Radojevic and Bashkin (2006) which is 0.01 – 2.0 mg/kg.

Zinc is an essential micro- nutrient to plants but when it occurs with other metals in high concentration, it can be significantly damaging to plants. The highest concentration for Zn was found in dumpsite from Oko-Olowo at 10meters and 40meters away from the core of the dumpsite (1205 mg/kg and 1290 mg/kg), respectively. The concentration could be attributed to the steel materials dumped at the site. The concentration of Zn from the Control sites ranged from 121.5 mg/kg – 195 mg/kg. This shows that the concentration of Zn analysed from the dumpsites were more higher than its concentration in the Control soil, that is the soil from the dumpsites were polluted compared to those from the Control. The mean concentration of Zn in the dumpsite soils ranged from 4.5 – 1,290 mg/kg, while the Control ranged from 121.5 – 195 mg/kg. In almost all the dumpsites, the values for Zn concentration were below the 300 mg/kg threshold level in soil (E.U.C.R, 2006) with the exception of Aran-Orin and Offa at different distances.

However the Zn concentrations in the dumpsite soils were higher than the World unpolluted soil average concentration of 70mg/kg (Kabata-Pendias, 2011) with the exception of soils from Offa and Ipee at 30meters away from the core of the dumpsites. This suggests that the soils are polluted. The Zn concentration reported in this work were higher than the target value of 140.0mg/kg (D.P.R, 1991) with the exception of Odo-Ore, Aran-Orin and Ipee at 10meters, Ipee at 20meters, Offa and Ipee at 30meters, Omu-Aran and Offa at 40meters away from the core of the dumpsites, but the mean values of these dumpsites were generally below the intervention value of 720mg/kg set for Nigeria soils by DPR (1991). The range of Zn concentration in soils of South Africa is given as 12-115mg/kg, and at established highest MTL value of 185mg/kg. The mean concentration in all the dumpsite soils analysed were higher than 44.5±4.1mg/kg obtained by Olajire *et al* (2003) in an industrial soil. The high concentration of Zn in Oko-Olowo at 10 and 40 meters away from the core of the dumpsite can be attributed to anthropogenic activities where structural building materials were dumped on the dumpsites. The concentration of Zn in the dumpsite soil with the exception of Oko-Olowo at 10 and 40meters fell within the normal range (1 – 900mg/kg) proposed by Alloway(1996) and Radojevic and Bashkin (2006).

Nickel concentration in soil samples collected from the dumpsite ranged from 0.00 – 19.5mg/kg, while the permissible range for Nickel is 0.005mg/l – 0.5mg/l (W.H.O.1984). Ni concentration in the dumpsites were lower than the 1 unit of 15mg/kg set for Denmark and Netherland soils (Table 32). Awokunmi *et al.* (2010) found Ni to be within the range of 0.2mg/kg – 450mg/kg, although the average is about 20mg/kg (Lenntech, 2009). The highest mean concentration of Ni (19.5mg/kg) in the studied area was found in Ipee at 40meters away from the core of the dumpsite. Generally, the Ni concentration in both the dumpsites and the Control site were below the threshold level of 50mg/kg (E.U.C.R. 2006) and the target value of 35.0mg/kg (D.P.R. 1991).

According to Helsmann *et al*. (2005), South Africa's soil contain Ni within the range of 3.43 – 159.0mg/kg and the maximum permissible level in agricultural soils established in 1997 was 50mg/kg. The concentration of Ni in the studied dumpsite soil fell within the normal range of metals in soil (2 – 750mg/kg) proposed by Radojevic and Bashkin (2006). Ni concentration in the plants was within the normal concentration range of 0.02 – 5.0mg/kg (FAO/WHO, 2007) with the exception of plants collected from Aran-Orin at 0 meters that had 5.5mg/kg concentration which was above the normal concentration of Ni in plants. The Ni concentration was below the critical plant concentration range of 10 – 100mg/kg (Radojevic and Bashkin, 2006) above which plant toxicity is likely. However, the concentration was above the acceptable limits (1- 5.00mg/kg) in food (Awashthi, 2000). Therefore, the plants from this dumpsites may be toxic to grazing animals and humans using these plants for food / medicinal purposes. The range of Ni obtained was lower than 7.92 µg/kg - 19.12 µg/kg reported by Alegria *et al.*(1991). The highest Ni level (5.5mg/kg) reported in this study was not in agreement with 0.45mg/kg and 1.33µg/g recorded by Ebong *et al*. (2007) and Yusuf *et al*. (2003), respectively

The heavy metal contents in plants collected from the dumpsites were higher than those collected from the Control site. This is an indication that with increasing concentration of metals in the soil, uptake of metals by the plants may also increase (Alloway, 1974). This also suggests that the heavy metal contents of plants depend on the concentration of its habitual soil environment (Ebong, 2008).

It was observed that Iron concentration was exceptionally high in the plants collected from the dumpsites. This does not agree with the result of Amusan *et al*. (2005) who studied the characteristics of heavy metals intake by crops cultivated on dumpsites where Zn had the highest mean concentration. The minimum and maximum concentration of Iron accumulated by plants

from the dumpsites were 195mg/kg and 4950mg/kg. Udosen *et ai*. (2006) reported a range of 630.10 µg/g – 742 .00µg/g for Fe in *Manihot utilissima* grown on a municipal dumpsite soil in Nigeria. However, the Fe range obtained in this study was higher than the range of 44.09 – 88.8µg/g reported in *Talinum triangulare* from a dumpsite in Obafemi Awolowo University, Ife. Nigeria by Amusan *et al*.(2005). The elevated range of Fe in the studied dumpsite could be attributed to the importance of the metals in plant growth, the high availability of Fe-containing waste and the abundance of Fe in the earth crust (Ebong *et al*., 2017, Harrison and Chirgawi, 1989). However, the plants assessed in this study was either fed on by animals or human, the elevated level of Fe concentration in the dumpsite calls for concern as it can cause some health implications such as vomiting, upper abdominal pain, cyanosis, diarrhoea, dizziness, shock, haechromatosis, diabetes, diseases of the liver, lungs and kidney, haepatoma and cardiomyopathy to the consumers (Dupler, 2001; Ferner, 2001). The results of this study agreed with Ebong *et al*.(2007) where Fe concentration in *Talinum triangulare* was higher than other metals. In this study Fe was predominantly detected in soil and plant samples than other metals. The concentration of Iron in plants from the various dumpsites ranged from 195mg/kg – 4950mg/kg. however, the concentration of Fe in plants collected from Offa and Aran-Orin at 10meters away from dumpsites, Omu-Aran, Offa, Aran-Orin and Ipee at 20meters, Aran-Orin and Ipee at 30meters, and Ipee at 40meters were below the permissible limits of 40 – 500mg/kg proposed by WHO/FAO while the plants from the other location were above the permissible limits. The Fe concentration were above the toxic level for Fe in plant leaves (300 – 500mg/kg) (Dobbermann and Fairhurst, 2000). These plants may pose health threat to grazing animals and humans using them for food/ medicinal purposes.

The mean concentration of Pb in plant samples collected from the dumpsites at varying distances ranged from 0.00 – 7.00mg/kg. These values indicated that Pb content in the plants growing on the dumpsite pose no threat to the health of humans and animals that consume these plants as the values were within the range of the generalized agronomic crop permissible level of 0.5 – 10mg/kg (Kabata-Pendias, 1991) and the permissible level of 0.43mg/kg for vegetables (E.U.C.R. 2006). In general, root vegetables are moderate accumulators while leafy vegetables are high accumulators (Alexander *et* al., 2006). Sillanpa and Johnson (1992) following their worldwide experiment in 30 countries reported Pb concentration in young wheat and corn plants to range from 0.2- <1mg/kg with highest Pb contents observed in plants from Belgium, Hungary, Italy, Malta and Mexico. Pb concentration in the plants in this study fell within the normal range in plant (0.2 – 20mg/kg) proposed by Radojevic and Bashkin (2006). Lead is injurious to plants as it has a higher affinity than the essential elements once it is absorbed by the plants; intake of essential elements is greatly reduced. This can eventually lead to the death of the plant (Fatoba, 2010). The accumulated Pb in plants also gained entrance into ruminant animals that feds on these plants and eventually lodge in man through the food chain causing serious health hazards (Fergusson *et al*., 1990). The result in this study agreed with the findings of Agyarko *et al*. (2010) who worked on the metal levels in some refuse dump soil and plants in Ghana. The obtained Pb concentration was lower than 34.97 – 83.92µg/g reported in *Talinum triangulare* from a dumpsite reported by Amusan *et al*. (2005), but higher than 0.34 – 0.71mg/kg reported in dumpsite plants by Udosen *et al*. (2006).

The mean Cu concentration in the plant was below the permissible level of 20mg/kg (E.U.C.R. 2006) for vegetables and fell within the range of generalized permissible level of 5 – 20mg/kg for agronomic crops (Kabata-Pendias, 2011). Reimann *et al*. (1999) and Fishelson *et al*. (1994)

stated that plants growing on Cu- polluted sites tend to accumulate higher amount of it especially near industrial areas, and in soil treated with Cu- bearing herbicides. The Cu concentration in all the dumpsites were below the critical plant concentration of 20 – 100mg/kg (Radojevic and Bashkin, 2006).

The mean Zn concentrations in some of the sampled plants were above the stipulated permissible level of 50 - 100mg/kg (Kabata-Pendias, 2011) for various crops and 50mg/kg for vegetables (E.U.C.R, 2006). The Zn concentration in plants from the dumpsites ranged from 16mg/kg – 310mg/kg. Only the plants samples collected from Aran-Orin and Ipee at 0 and 10meters, Omu-Aran, Offa, Aran-Orin and Ipee at 20meters, Omu-Aran, Ipee and Aran-Orin at 30meters and Omu-Aran, Aran-Orin and Ipee at 40meters were below the the standard recommended by WHO and NAFDAC while the other plants collected from the various dumpsites were above the permissible limit. The Zn concentration in the plants were within the critical plant concentration range of 100-400 (Radojevic and Bashkin, 2006) above which plant toxicity is likely to occur. The high Zn concentration in the sampled plants is explainable, since Zn is an essential trace element for humans, animals and higher plants (Alloway, 1996; Pahalawattaarachchi *et al.,* 2009). Zn is an essential elements to plant growth and it is needed in small quantity, however excess concentration in plant tissues may cause toxic symptoms such as reduction of root growth in the less tolerant plants (Rauna *et al*., 2004). The Zn concentration obtained in this study was higher than 19.23 – 24.73µg/g reported in *Talinum triangulare* from Ife dumpsite by Amusan *et al*. (2005).

Cd concentration in the plants collected from the dumpsites were within the normal concentration range proposed by WHO/FAO and within the normal range in plants. The Cd concentration recorded in the plants collected from the dumpsites ranged from 0.00-0.50mg/kg,

the low concentration of Cd in the plant can be attributed to the metal being non-essential for plant growth and metabolism (Shaibu and Ayodele, 2002). Cadmium range recorded in this study was however not high enough to cause plant toxicity. According to Vecera *et al*. (1999), phytotoxicity can occur above the range of 0.1 – 1.2mg/kg. Nevertheless, the range of Cd in plants collected from the dumpsite under study was higher than 0.03 – 0.05mg/kg but lower than 1.13 and 1.63mg/kg reported by Udosen *et al*. (2006) and Yusuf *et al*. (2003), respectively. The concentration of Cd in the plants collected from various dumpsites under study agreed with the findings of Ebong *et al*. (2007) who reported the concentration of Cd as 0.10 – 0.30mg/kg when they worked on the accumulation of heavy metals by *Talinum triangulare* grown on waste dumpsites in Uyo metropolis, Akwa Ibom, Nigeria.

The high concentration of heavy metals in plant samples collected from the dumpsites could be attributed to high metal concentration in the soil. The heavy metal concentrations of plants from the Control sites were lower than those from the dumpsites. This suggests that the heavy metal concentrations in the plant were gotten from the soil. This agreed with the findings of Ebong *et* al.(2008) which stated that the heavy metal contents of the plant depend on the concentration of its habitual soil environment. The high concentration of heavy metals in the dumpsite soil and plants could be due to the fact that wastes dumped there originated from domestic and industrial activities which are sources of refuse and waste that are also the sources of heavy metals (Aekola *et al*., 2008). This also contributed to higher concentration of heavy metals in farmlands around the dumpsite due to the mobility of metals from the dumpsite to the farmland through leaching and runoff and its eventual uptake by plants and crops resulting in bioaccumulation and its transfer to the food chain (Opaluwa *et al*., 2012).

In almost all the dumpsites, the concentration of the metals in the plants bore a resemblance proportion with the metal concentration in the soil and therefore in most cases, the metal loads of the plants from the dumpsite soil were higher than those from the Control site. This is in agreement with the findings of Ebong *et al*. (2008) who attributed the situation to the high metal content of its habitual soil environment. The high level of heavy metal in the dumpsite soil and plants can also be attributed to large amount of waste products disposed off at the dumpsite, although aerial deposition of these metals could be another source to soil and plants (Onianwa, 2001; Onianwa and Egunjobi, 1983; Yusuf *et al*., 2003).

The distribution pattern of heavy metals between the different dumpsite soil and plants were highly variable. This could be attributed to the variations in age, distances from the core of the dumpsite and the content of the waste / type of the waste dumped. The general finding in this study agreed with the report by Amusan *et al*. (2005); Ebong *et al*. (2007); Odukoya *et al*. (2000), Udosen (1994), Udosen *et al*. (2006) and Yusuf *et al* (2003), that dumpsite soil and plants have higher metal concentration than their soil and plants samples from the Control sites.

Accumulation/ Transfer Factor of heavy metal is essential to investigate the human health risk index (Cui *et al*., 2005). Values greater than 1 indicate a net accumulation by the plant and potential phyto-extract heavy metals (Juarez-Santillan *et al.*,2010 and Li *et al*., 2007), whereas values below 1 shows net accumulation in the soil. The plant species collected from the dumpsite at 0meter in Oko-Olowo are hyper accumulator for Pb, Ni, and Cu as the TF is greater than 1. At 10meters, the plant collected from the dumpsite in Aran-Orin and Odo-Ore were hyperaccumulator for Zn and Ni. At 20meters, plant samples collected from Odo-Ore were hyperaccumulator for Pb, Ni, Cu, and Fe while in Oko-Olowo, Cu was hyperaccumulated in the plants gotten there. Plant samples collected from Oko-Olowo and Offa at 30meters were

hyperaccumulator for Cu and Zn respectively. Plant samples collected from Omu-Aran and Offa at 40meters are hyperaccumulator for Ni and Cu respectively. The plant samples collected from the Control sites were also hyperaccumulator for Pb, Cd and Cu. The general high accumulation of the heavy metals in the sampled plants especially the plant from the Control sites may be due to atmospheric deposition of the metals from non-ferrous metal activities, fossil combustion etc. which may be absorbed into the foliage and translocated into the plants. In green spinach grown near a waste dumpsite in Gombe, Nigeria the accumulation factor of 2.41, 2.07 and 1.29mg/kg was reported for Cd, Pb and Zn, respectively (Onyedika and Okon, 2014). Chen *et al*. (2009) reported that Cu^{2+} ion inhibits Ni^{2+} ion influx and uptake competitively as they are absorbed by the same transport system in plants. The result of this work showed that the accumulation of Cu was higher than Ni which is in agreement with the early findings of Zabin and Howladar (2015) that Cu was accumulated in the plants species collected from all the dumpsites than Ni. The findings in this work did not agree with an earlier work by Shittu *et al.* (2015) that showed that Ni accumulation was higher than Cu accumulation in the plants investigated.

The transfer factor of Pb, Cd and Cu from the Control sites with lower concentration of heavy metals were higher than those from the dumpsites soils with higher metal loads. This indicates that some soil factors apart from the total soil contents of the metals affect the rate of metal uptake by the plants. This was the same observation made by Agyarko *et al*. (2010) who worked on the metal levels in some refuse dump soils and plants in Ghana. The application of some materials like dolomite, phosphate or organic matter into the soil were found to reduce the concentration of metals by precipitation, adsorption or complexation, thereby making them unavailable to plants (Chen and Lee, 1997; Mench *et al*., 1994). Agyarko *et al*. (2010) observed higher level of organic matter content, available phosphorus (phosphate) and exchangeable

cations such as Ca and Mg therefore resulting in lower transfer ratio of the metals in the refuse dump soil than the background soil (Control) as observed in this work. Variation in transfer factor among different plants may be attributed to differences in the concentration of metals in the soil and differences in element uptake by different vegetables (Cui *et al*., 2004).

Cu showed the highest TF of 26.35, this high metal accumulation may be attributed to a well-developed detoxification mechanism based on sequestration of heavy metal ions in vacuoles, by binding them on appropriate ligands such as organic acids, proteins and peptides in the presence of enzymes that can function at high level of metals (Cui *et al*., 2007) and metal exclusion strategies of plant species (Ghosh and Singh, 2005). The variation in values observed for the heavy metals in the dumpsite soil and plants samples as against those from the Control sites is an indication of the mobility of this heavy metals from the dumpsites to the farmlands around especially through leaching and runoffs. This is also in agreement with the report of Oluyemi *et al*. (2008) and Opaluwa *et al*. (2012).

The degree of pollution of the refuse dumpsites by the metals was assessed using the Geo-Accumulation Index (Igeo) classification Table by Forstner *et al.* (1993) and Oyekunle *et al*.(2011). The calculated Geo-Accumulation Index results showed that all the dumpsites were unpolluted to moderately polluted with Cd, Zn, Ni, Cu and Fe while the dumpsite was moderately polluted with Pb to strongly polluted in all the dumpsite. Ipee seems to be more polluted with Pb than the other dumpsites. Of all the dumpsites under study, Ipee seems to be more polluted than the other dumpsites with the soil being strongly polluted with Pb. This may be due to the fact that the dumpsite is located closely to an automobile and auto body repair workshop. The classification showed that the refuse-dumped soil from Omu-Aran was the least polluted with the heavy metals, which may be due to the low population in the area where the

dumpsite was situated and constant burning of the refuse dumpsite by the Local government environmental health workers there. The pollution of soil by Pb is a very serious problem that have been given much attention by environmental chemist. This is due to the fact that Lead is a cumulative pollutant (Dara, 1993) and the continuous disposal of Pb containing waste into the environment should be discouraged.

Peter (2000) discovered that heavy metals are toxic to plants and the first sign of toxicity is reduction in yield due to the resulting adverse effects on the crop's productivity. The result and observation in *Abelmoschus esculentum, Corchorus olitorious* and *Solanum lycopersicon* agreed with the findings that there was reduced shoot height in those planted on dumpsite soil which had a higher heavy metal content than those with Biochar application and the Control but the observation in *Amaranthus esculentus* and *Tithonia diversifolia* did not agree with this as there were increase in the growth parameters on Dumpsite soil than other treatment, which may be as a result of high organic content in the soil. Peralta *et al*. (2001) also discovered that 40ppm of Cr (VI) reduced the ability of Lucerna (*Medicago sativa*) to germinate and to grow in contaminated soil by 23%. The findings from this study showed reduction in the growth parameters in *Abelmoschus esculentum, Cochorus olitorious* and *Solanum lycopersicon.*

The result of the experiment carried out by Opeolu *et al.* (2010) showed that tomato plant performance generally depreciated with an increase in the concentration of Pb. The result also reported that there were no significant differences ($p < 0.05$) in the tomato stem height in all the concentrations studied. The result from this work supported this study as there were no significant differences in the stem height of tomato at 2WAP, but at the other weeks after planting, there were significant differences among all the treatments. It was also observed that the shoot height of *Solanum lycopersicon* in the Dumpsite soil was significantly higher than the

other treatments for tomato from 6WAP up to the time of harvest. The extent of absorption of the metals by plants depends on the nature of the plant, the chemical composition of the pollutant, concentration of the element present in the soil, interaction with other metals present in the soil and the soil pH (Zurera *et al*., 1989).

Leafy vegetables has a greater potential of accumulating heavy metals in their edible parts than grain or fruit crops. Studies on the uptake of heavy metals by plants have shown that heavy metals can be transported passively from root to shoots through the xylem vessels (Krigger *et al.,* 1999).In addition, the plant organs that has low transpiration rate do not accumulate heavy metals because the storage organs are largely phloem-loaded and heavy metals transported in the phloem poorly (Davies *et al.,* 2002). This may be the reason for the low heavy metal concentration in the fruit of Okra and in the shoot of the plants used in this experiment in comparison to the root that accumulated more heavy metals.

Zn is an essential metals in plant growth. It is important to note that Zn^{2+} at low concentration promotes the growth parameters in comparison to their Control (Tang *et al.,* 2009). The result of this study agreed with this statement as the soil from the dumpsite has a reasonable amount of Zn and the growth parameters and yield in tomato and okra increased in comparison to the Control. The enhancement effect of the heavy metal (Zn^{2+}) at low concentration on growth parameters was reported by Ismail and Azooz, (2005) and Sharma *et al.* (2009). This work agreed with their findings as there was an increase in the growth parameters in Okra and Tomato because the concentration of Zn was low in the soil used for planting. This may also be attributed to its beneficial role in plant growth and development. Wierzbicka and Obidziska (1998) stated that Zn is an indispensable micro-nutrient for plant growth.

Excessive supply of heavy metals may prevent the incorporation of Fe in phytoporphyrin molecules resulting in the reduction of chlorophyll pigment (Jaleel *et al*., 2009; Nyitrai *et al*., 2002). This work agreed with their study as the crops on Dumpsite soil and Biochar with Dumpsite soil started turning yellow (chlorosis) from 4WAP. The reduction in photosynthetic pigment by excess heavy metals and an increase of carotenoids content have been reported by Ismail and Azooz, (2005) Sharma *et al.* (2009) and Hamid *et* al. (2010). Reduced growth and biomass production are responses of some plants to heavy metals toxicity are often a reliable indication of plants to their stresses (Korobrukhov *et al*., 2004; Vaillant *et al*., 2005; Shaarma *et al.,* 2009). The reduction in growth could be due to the reduction of the elongation growth cells as reported by John *et al.* (2008). This may be the cause for the reduction in the physiological growth of all the crops investigated in the experiment on the dumpsite soil at 2WAP. Guo *et al.* (2007) showed that the synergistic effects of heavy metal burdens are significantly more toxic than the individual heavy metal exposure.

Copper is an essential element for plant growth. This microelement is needed for the composition of many enzymes in plants, but it must be in little quantity as it may become very toxic in high concentrations (Radulescu *et al.,* 2013). In this study, copper concentration exceeded the maximum admitted limit (MAL) according to (JECFA, 2005) for raw vegetable leaves (5 mg/kg) except for Okra planted on Biochar with control soil that was below the maximum admitted limit of all analyzed samples. The Cu concentration in all the plants planted and analyzed exceeded the normal range in the plant (5-20mg/kg) according to FAO/WHO with the exception of Okra shoot and root in Biochar with dumpsite soil and Biochar with control soil respectively. All *Corchorus olitorious* shoot did not exceed the normal range in a plant with *Tithonia diversifolia* shoot in Dumpsite soil and Biochar with control soil, *Solanum lycopersicon*

root in Biochar with control soil with the Okra fruit in all the soil treatment did not exceed the normal range in plant proposed by FAO/WHO. The highest Cu concentration was found in *Solanum lycopersicon* root (4698.26mg/kg) while the lowest concentration was found in Okra planted on Biochar with control soil.The soil used for planting of the crops were from the dumpsite which had a high Cu concentration while the lowest concentration was found in Biochar with control soil as biochar has been discovered to absorb and remediate soil with high heavy metal concentration and the soil to which it was added was from an unpolluted site.

Cadmium is a non-essential micro-nutrient, which has not yet have an established biological role, which tends to be toxic to plant at high concentrations (Radulescu *et al.*,2013). Cadmium accumulation in plants depends on plant species and the metals in a soluble form in the soil. It was noted that Cd concentration in this experiment fell within the normal range in plant by FAO/WHO (< 2.4mg/kg) in vegetables with the exception of Okra shoot and root planted on Dumpsite soil, *Corchorus olitorious* root planted on Dumpsite soil and Biochar with dumpsite soil, the root of *Amaranthus esculentus* on Biochar with dumpsite soil, *Tithonia diversifolia* shoot and root in Dumpsite soil and Biochar with dumpsite soil with *Solanum lycopersicon* shoot on Dumpsite soil and its root in Dumpsite soil and Biochar with dumpsite soil. It was noted that those that exceeded the normal range in vegetables were from the dumpsite soil while others were from the Biochar with dumpsite soil, the reason being that the Biochar reduced the Cd concentration in them but was still above the normal range. It was discovered from this study that the roots had very high heavy metal concentration when compared with the quantity of the heavy metals absorbed by the shoot. This agreed with Radulescu *et al.* (2013) who worked on the accumulation of heavy metals on cabbage where their root absorbed up to 9 times the Maximum Allowable Limit of Cd. The root is adapted to carry out the following functions: fixing plant in

the soil, absorption of water and dissolved minerals. The root contributes to the metabolism of feeding the whole plant and often serves as storage organ for soil minerals (Radulescu *et al.,* 2013). The ability of the root to accumulate high heavy metal concentration is a means for the protection of the aerial parts of the plants (Radulescu *et al.,* 2013). Adsorption of heavy metals and their transportation to the plant parts depend mainly on the type of metals, its biological role in the plants, and its ability to form some complexes with the sap components (Radulescu *et al.,* 2013).

Results from the planting experiments demonstrated the significant role of biochar in plant's physiological growth. The biochar's benefits were mostly seen when biochar materials were combined with Control soil which produced plant growth than when compared to Control soil only. For the biochar's treatment, increase of dry matter biomass relative to the control were observed only in Okra while the other crops do not have an increased biomass production with biochar application., this agreed with the work of Hossain *et al.*(2010) and Hossain *et al* . (2015) where they reported an increase in biomass production in the control soil than sewage sludge biochar effects on tomato and similar results was also reported for rice shoot weight (Khan *et al.,* 2013).Plant growth response to biochar application was related to improvements in the soil. Biochar application increases the shoot height in *Abelmoschus esculentum, Corchorus olitorious, Solanum lycopersicon* and *Amaranthus esculentus* and reduced the heavy metal concentration. The results of this study agreed with previous research which demonstrated direct contributions of mineral nutrients in the biochar ash component which plays an important role in remediating acidic soils and promoting plant physiological growth (Butnan *et al.,* 2015; Deenik *et al.,* 2010,2011; Smider *et al.* 2014; Xu *et al.* 2011).

Various researchers have reported different effects of time on biochar performance. In a greenhouse experiment evaluating the use of Flash Carbonized corn cob biochar applied to an acid Ultisol, the positive impacts were for a short time and did not continue beyond the first crop cycle (Deenik *et al.*, 2011). In contrast, a Flash Carbonized eucalyptus biochar showed no effect on plant growth in the first crop but produced significant benefits to plant growth in the second crop (Butnan *et al.*, 2015). This work agreed with the result that there was no significant difference between those with biochar and those without biochar at the end of the experiment. At the field scale, there were some evidence that biochar benefits to crop growth are not realized in the first crop cycle, but takes time to manifest the effect (Major *et al.* 2010; Quilliam *et al.*, 2012, 2013). This may be the reason for the reduced shoot height and number of leaves in the crops which had Biochar when compared with the Control. There is a maturing body of evidence to show that sewage sludge biochars reduced heavy metal presence in the soil and their accumulation in plants (Fellet *et al.* 2014; Hossain *et al.* 2015; Khan *et al.* 2013; Liu *et al.*, 2014; Mendez *et al.*,2012). This work agreed with the finding that there was reduced heavy metal accumulation in treatment with biochar application.

Metal concentrations in the crops were below the WHO maximum permissible concentrations in crops and the results support the general trend that biochar reduces heavy metal availability, the lack of a significant effect compared to the Control soils from an agronomic perspective is important because it suggests that the biochar is not a source of metal contamination for food crops allaying the potential concerns from a food safety perspective. The concentrations of metals in plant tissues showed different results among all the treatments. Soil phytoavailable metal pools following biochar application decreased for all heavy metals in all the crops under

study with the exception of *Amaranthus esculentus* that showed an increase in Ni concentration in the treatment with Biochar application.

After plant's harvest, the Cd concentration in the shoot and root of the crops in all the treatments (at the rate of the 25%) reduced significantly ($p \leq 0.05$) with the exception of *Amaranthus esculentus* that was not significantly different in all the treatments. This observation agreed with the results of Zahra *et al*. (2017) where they reported a reduced Pb accumulation in the root of mustard green plant. Results indicated that the addition of Biochar into the dumpsite soil and the Control soil reduced the concentration of Cu in the crop shoot. This also agreed with Zahra *et al. (*2017*)* who reported that the addition of amendments in different application rates only slightly reduced the concentration of Cu in plant leaves. With the exception of *Tithonia diversifolia* which had an increase in the Cu concentration in the treatment with Biochar application in this study, all other test plants recorded decrease.

Biochar application was effective in decreasing the concentration of Pb in aerial parts of all the crops used in this study. This findings agreed with Zahra *et al.* (2017) where they observed a decrease in Pb accumulation in all the treatments with Biochar application in mustard green in comparison with the control. The addition of Biochar decreased Zn accumulation in plant shoots with the exception of *Amaranthus esculentus* that had an increased Zn concentration in the root. Biochar application caused a significant reduction ($p > 0.05$) in Zn uptake by the plants. However, all the crops used in this study were hyperaccumulators especially the root system which had a far greater concentration of heavy metals

The results from this study demonstrated the ability of root systems to absorb high contents of heavy metals. This observation agreed with Zahra *et al.* (2017) results which reported that root systems have the ability to absorb high content of Cu through the soil. The remediation system

displayed mass balance successfully within the soil, plants, and leachates. The total concentrations of Cd, Cu, Pb, Ni, Fe and Zn in the crops changed when Biochar was added. Noteworthy was that there was no negative environmental side effect of using biochar or risk on surrounding ecosystem observed. On the contrary, using Biochar in high-application dosage could induce metal concentration in soil and subsequently their availability, but also reduced plant biomass. Therefore, finding the most efficient application dosage of biochar is a big concern to manage remediation process in agricultural soils.

Various agronomic effects of soil biochar additions on crop productivity have been shown in many studies such as Chan *et al*. (2007), Feng *et al*. (2014), Glaser *et al*. (2002) and Steiner *et al*. (2007). Even though the exact mechanism at which it occurred has not been fully known, the improvement of crop productivity has been attributed to the increase in soil available nutrients (Asai *et al*., 2009; Uzoma *et al*., 2011a) and enhanced soil physical properties (decreases soil bulk density, increases water holding capacity) after the incorporation of biochar (Brockhoff *et al*., 2010; Akhtar *et al*., 2014). From this work, the addition of biochar has been seen to increase the physiological growth of the plants at their early stage. This is in support of the findings of Chan *et al.* (2007) and Glaser *et al.* (2009). Asai *et al*. (2009) discovered higher productivity rates in biochar amended soils which are related to the improvement of soil conditions which in turn brings about an increase in yield due to an increase in plant-available P content. This may also be due to the biological alterations in soil following the addition of biochar which may include changes in the composition and abundance of the biological community, as well as enzyme activities as stated by Lehmann *et al*. (2011).

Vegetables shows different ability in a bid to take up and accumulate heavy metals, even among cultivars and varieties within the same species (Zhu *et al.*, 2007; Samuel *et al.*, 2012). According

to Yang *et al.*, (2009, 2010) who reported that Cd uptake and retention in leafy vegetables are greater than in non-leafy vegetables. In this study, significant differences were found in the concentrations of heavy metals in the edible parts of different vegetable types; the concentrations decreased in the order of root> shoot and leaves > fruits. In addition, the ability of heavy metal uptake and accumulation of leafy vegetables was higher than the other vegetable types, and the ability of *Corchorus olitorious* was the lower. *Amaranthus esculentus, Abelmoschus esculentum, Solanum lycopersicon* and *Tithonia diversifolia* had higher heavy metal concentrations of Fe, Cd, Zn, and Pb. The elevated concentration levels of heavy metals and the strong ability for heavy metal accumulation in leafy vegetables were possibly due to the leaves being the main parts of the vegetables used for photosynthesis, because higher metal mass flowed to the leaves due to strong transpiration (Marchiol *et al.*, 2004, Perfus-Barbeoch *et al.*, 2002 and Zhou *et al.*, 2013). The leaves were also easily exposed to contaminated soil because leafy vegetables were generally short plants with their leaves closer to the ground than the other types of vegetables.

Furthermore, atmospheric heavy metal deposition might be one of the reasons for elevated metal concentrations in leafy vegetables in mining and smelting areas (Huang *et al.*, 2006; Sharma *et al.*, 2008). Obvious differences in accumulation of heavy metals (Pb, Cd, Cu, Zn, and Fe) were found in the same vegetable species. The Fe, Zn and Cu concentrations in the plants were higher than Cd, Pb and Ni in all the studied plants. These probably were because Fe, Cu and Zn were the essential elements for vegetables growth (Rahman *et al.*, 2013), and were readily accumulated in roots and transported to aerial part (Zhou *et al.*, 2015) while Pb, Cd and Ni are toxic elements and are not required for vegetables growth, they were stored in roots, and their transport to aerial parts of the plant were limited (Yang *et al.*, 2008; Liu *et al.*, 2007).

Generally, Cu and Zn which are important nutrients for humans are considered a much lower health risk to humans than Pb, Cd, and Fe (Alexander *et al.,* 2006). Poor health can be caused by a lack of these required elements (Zhu *et al.,* 2011), but excessive ingestion can also have adverse effects on human health (Hu *et al.,* 2013; Rahman *et al.,* 2013). Lehmann *et al.* (2006) noted that crops respond positively to biochar additions up to 55 tons/ha, showing growth reduction only at very high applications. This statement was found to be correct in this work as the plant growth started reducing after 4WAP. This may be due to the 25% of biochar used. Biederman and Harpole (2013) also confirmed a reduction in yield due may be due to a high biochar application rate. When an equivalent of 165 tons/ha of biochar was added to a poor soil in a pot experiment (Rondon *et al.,* 2007), yields decreased to the level of an unamended control. According to Kammann *et al.* (2011) who found that quinoa growth was retarded at 100–200 tons/ha. Others have reported thresholds at much lower levels. Asai *et al.* (2009) reported greater rice yields with 4 tons/ha of biochar compared with 8 or 16 tons/ha applied, with the higher application rates providing yields not different from the unamended control. The reasons for these decreases are not known; further study is necessary to determine which biochar materials are best suited for application and at which rates to specific soils. The recommended application rates of biochar as a soil amendment are quite different providing the insufficient field data available to make general recommendations on the soil types and crops needed for biochar's application (David *et al.,* 2013). Additionally, the materials needed for biochar production widely different in their characteristics (e.g., pH, nutrient levels, ash content) which would also affect their application rate (David *et al.,* 2013). Since biochar does not appreciably decompose in the soil, a single application can provide positive effects over several growing seasons in the farmland (Steiner *et al.,* 2007) as is not usually the case for manures, compost, and conventional

fertilizers. However, most biochar materials, unless derived from manure or blended with nutrient-rich materials, do not substitute for conventional fertilizer, so adding biochar without necessary amounts of nitrogen (N), phosphorus (P) and potassium (K) should not be expected to provide improvements to crop yield (David *et al.*,2013). As biochar is expected to have a lasting soil benefits, whereby it is not needed to be added to the soil after each growing year as is the case with many agricultural/conventional fertilizers, the effect exists where it may improve otherwise infertile soils into the future (David *et al.*,2013).

Biochar from woody materials is typically a soil enhancer, enhancing the pH, soil water relations, and CEC, resulting in improved crop yields (Uzoma *et al.*, 2011). In addition, biochar from agricultural livestock waste such as cow manure and poultry litter has the added benefit of providing higher levels of essential nutrients (N, P, and K) (Covell *et al.*, 2011). However, not all the nutrients contained in the biochar are available to plants as additional research is necessary to understand how manure biochars interact with specific crops and soils to reduce nutrient leaching and increase nutrient uptake in crops (Ippolito *et al.*,2012). The addition of fertilizer with biochar application can lead to increase in plant growth and yield (Chan *et al.*, 2007; Asai *et al.* 2009; and Saarnio *et al.* 2013) but a negative effect is sometimes observed without fertilization, due to reduced bio-availability, through sorption of nitrogen (Savalloni *et al.*,2011; Case *et al.*,2012). This statement agreed with the findings of this work was reduced physiological growth towards the termination of the planting experiment but if fertilizer had been used, there could have been an increase in the yield.

The Control crops were observed to be susceptible to insect infestation. This is in support of the findings of Serah *et al.* (2013) where the researcher observed insect infestation, although a number of factors can contribute to plant death with smaller plants being more susceptible to

attack by insects. There was increased Cu concentration in the root of *Corchorus olitorious* planted in Biochar with dumpsite soil. This result agreed with Beesley *et al.*(2010) where there was increased Cu concentrations in pore water which was associated with elevated concentrations of soluble carbon from biochar. Applying the amendments individually or in combination resulted in an initial high Cu concentrations, but reduced over several growing cycles (Beesley *et al.,* 2010).

Amendment of dumpsite soil with biochars as done in this study resulted in gradual reduction in heavy metals concentration in the soil. This may be attributed to the ability of biochar to increase soil pH which may have increased sorption of these heavy metals by biochar surfaces, thus reducing their bioavailability in the soil for plant uptake. This assertion agreed with the findings of Park *et al.* (2011) who reported that, the large surface area of biochar and their high cation exchange capacities enhance the sorption of both organic and inorganic contaminants to their surfaces; thereby reducing pollutant mobility in contaminated soils. Beesley *et al.* (2011) reported that retention of heavy metals on biochar surfaces has proved that sorption of these metals was produced at the biochar surface and this process was irreversible immediately. Biochar may also immobilize heavy metals by transforming the readily available fractions to a more stable residual fractions, thereby resulting in reduced mobility and bioavailability of heavy metals (Ahmad *et al.,* 2014).

Moreover, due to Biochar' unique characteristics, Paz-Ferreiro (2014) suggested that biochar is more suitable than other materials to remediate different organic and inorganic contaminants in the soil. The non-significant effect of biochar on the growth parameters of *Amaranthus esculentum* in this study may be attributed to the high native fertility status of the dumpsite soil used and when *Amaranthus esculentum* was planted, the growth was spontaneous. This agreed

with the findings of Amusan *et al.* (2005) who worked on the characteristics of dumpsite soils and the uptake of metals by plants. The uptake of Pb, Ni, Fe and Cu were significantly reduced when biochar was applied compared to control treatment. Biochar in the polluted soil resulted into a gradual decrease in the entire heavy metals uptake by *A. esculentum*. The reduction in the concentration of heavy metals in *A. esculentum* in biochar-amended polluted soil can be attributed to the immobilization of available metals (Park *et al.,* 2011).

A delayed response/ suppression of plant growth/ emergence can occur with biochar amendments (Major et al., 2010). This alteration in the response is considered to be a result of the weathering or aging of the biochar in which the biochar is physically, biologically, and chemically altered, thus affecting the seed emergence and seedling growth. Deenik et al. (2010) observed that the suppression/ delayed response of plant was due to the presence of volatile organic compounds adsorbed to the biochar. In fact, it is known that pyrolysis of biomass materials generates chemical species that can be plant-microbe stimulants (e.g. increased seedling vigor, seed emergence, and root development) as well as chemicals that are plant inhibitors (Nelson *et al*. 2012). The trends observed in the findings of this study with increase, decrease, and no differences among seed emergence are similar to results from previous biochar studies. Solaiman *et al*. (2011) reported that low rates of biochar amendments of rice husks, metallurgical charcoal, and wheat chaff usually increased wheat seed germination, and higher biochar application rates had no effect or decreased germination. This could be due to a homeostatic effect (Jaiswal *et al*., 2014), in which low concentrations of a chemical can result in stimulation while higher concentrations can reduce plant growth. This might be the reason why there was no significant difference in the yield of the crops with biochar and those without because 25% of biochar was used during the experiment.

Biochar can contain some plant nutrients and chemical compounds from the original biomass and compounds created during pyrolysis which may have impacted seed emergence in positive or negative ways in this greenhouse study, similar to the research on compounds in wood smoke (Nelson *et al*., 2012; Spokas *et al*., 2012) Consistent with other recent research into the impact of fast pyrolysis biochars, there is the potency for negative effects on plants (Deenik *et al.*, 2010). The result from this study suggests that temporary biochar suppression of plant height can be eliminated with sequential growth periods or weathering. This indicates that negative effects from biochar additions are transient in nature. There have been hypotheses that biochar weathering in the field increases cation exchange capacity and surface oxygen moieties (Major *et al*., 2010), leading to increase in the CEC capacity and thus nutrient retention.

Weathering of biochar has also reduced the mitigation effect of biochar on N_2O emissions (Spokas, 2013). The result showed that biochar weathering due to successive plant growth periods can be eliminated within 68 days for spinach grown in 10% w/w macadamia nut shell biochar. Laboratory studies have also tested the reaction of various plants to biochar-amended soil in pot trials. Chan *et al*., (2007) studied greenwaste biochar on radish yield using an Alfisol soil. The researchers concluded that the results were no different from the control when biochar was used alone. The findings of this study agreed with this as there was no significant difference in the yield. When Nitrogen was added to varying levels of biochar and amended to the soil, the results were very positive with regard to higher radish yield particularly at higher levels of biochar and the interaction between biochar and Nitrogen provided better results than Nitrogen alone.

Additional benefits to the soil were also realized with the biochar and Nitrogen combination, with pH, Organic carbon, and Exchangeable cations, all increasing while tensile strength

decreased. The application of biochar increased the shoot height and number of leaves in *Abelmoschus esculentum* at 2WAP- 6WAP. This observation agreed with the findings of Olaniyi and Ojetayo (2011) where they observed significant increase in leaf length and number of leaves from 4-12 weeks after sowing with the application of biochar. In order to identify the real effect of biochars, it may take some years as no significant effect of application rates was observed on plant growth in the first and second years of application but it was significant in the third year when it was applied at 0, 25 and 50 t ha (Jones *et al*., 2012).

The lower plant height at greater than 30 t ha^{-1} in onion and 50 t ha^{-1} in tomato indicated some negative effect of biochar on plant growth. This effect could be due to increased stress from the accumulation of salts on the surface of biochar applied at higher rates (Naz *et al*., 2013). Shoot lengths of *Abelmoschus esculentum* were significantly different (P> 0.05), hence there were higher amount of heavy metals in the dumpsite soil which might have reduced the shoot height of the crop planted on the dumpsite soil. This findings agreed with the work of Naz *et al*. (2013) who worked on *S. oleracea* where he observed a decrease in the shoot height and effects of the addition of Cd, Pb and Zn concentrations as well as their mixtures. However, increase in shoot length was observed in *Corchorus olitorious, Amaranthus esculentum, Tithonia diversifolia* and *Solanum lycopersicon.*

Cadmium inhibits plant growth, and its toxicity increases with increasing Cd concentration in soil. In the present study, increase in the concentrations of Cd in the dumpsite soil significantly (P> 0.05) reduced shoot height. The results of this study are in agreement with the findings of previous research (Naz *et al*., 2013; Ebrazi Bakhshayesh *et ai* ., 2014; Sun *et al.,*2008; Lingua *et al.,*2007). However, the results of the present study are not consistent with other published findings (Lin *et al.,* 2007; Vogel-Mikus *et al.,* 2007). High concentrations of Cd in soil led to

toxicity in plant biomass and plant heights of *Abelmoschus esculentum,* which agreed with the findings of previous work (Shukla *et al.,* 2007; Naz *et al*., 2013). Cadmium toxicity is more severe within roots in terms of both biomass and length (Naz *et al.*, 2015). The roots of the plants are more sensitive to heavy metal concentration than shoots because they are part of plants, which first come into contact with toxic substances (Naz *et al*., 2015). The findings in this study was in line with this observation as there was higher heavy metal concentration in the root of all the plants under study than the shoot. Liu *et al.* (2004) reported that a reduction in the formation of new cells under the influence of Pb and Cd leads to a reduction in shoot lengths also. Zinc is an element that is necessary for plants growth, but its excess can significantly damage plants (Wang *et al.,* 2009). The soil with high Zn concentration has a high concentration of heavy metals in their plants with the exception of Okra root that has a higher concentration on Biochar with dumpsite soil than Zn concentration in the Dumpsite soil. Shoot and root (fresh and dry) weights reduced with increasing concentrations of Zn. Zinc reduced plant biomass because it led to a deficiency of macro-nutrients such as phosphorus (Sun *et al.,* 2008*)*. An *et al.* (2004) also reported reductions in the growth of corn with increasing concentrations of Zn.

The partitioning of heavy metals is well known, with an accumulation of greater concentrations in the edible portions of leafy or root crops than the storage organs or fruits (Jinadasa *et al*., 1997; Lehoczky *et al*., 1998; Sharma *et al*., 2006). The findings in this study agreed with this statement as there was greater accumulation of heavy metals in the shoot than the fruits.According to Odai *et al.* (2008) who studied the concentration levels of heavy metals in vegetables grown on urban waste dumpsites. He carried out the study on three waste dumpsites in Kumasi where he cultivated vegetables (cabbage, lettuce and spring onions) were practised. Crops and soil samples were collected and analyzed for the presence of four heavy metals:

Cadmium, lead, copper and zinc. The levels of the two most toxic heavy metals were far higher in the vegetables than the WHO/FAO recommended values and the transfer factors of these two metals were also the highest suggesting that consumption of vegetables grown on such sites could be dangerous to human health. This observation agreed with the findings of this study as there was higher concentration of Cd and Pb in the crops planted on the dumpsite soil and Biochar with dumpsite soil in Okra, *Corchorus olitorious, Tithonia diversifolia* and *Solanum lycopersicon.*

Chove *et al*. (2006) carried out a study to determine the levels of two heavy metals, Lead (Pb) and Copper (Cu), in two popular leafy vegetables grown around Morogoro Municipality in Tanzania. Pumpkin leaves (*Cucurbita moschata*) and Chinese cabbage (*Brassica chinensis*) were collected from three sites and analyzed for their concentrations for Pb and Cu using an Atomic Absorption Spectrophotometer. The results showed that the levels (mg/100 g dry weight) ranged from 0.885 to 1.39 for Copper and 0.05 to 0.315 for Lead. The levels of Lead and Copper varied between the vegetable varieties and from site to site, there was a significant difference ($P>0.05$) in levels of the two metals across the sites but there was no significant difference ($P<0.05$) in the levels of Copper between the two vegetable varieties from all the three sites. There was a significant difference ($P>0.05$) in the levels of Lead between the vegetable varieties. The levels of both Lead and Copper in the two vegetables were found to be below the maximum permissible levels recommended by FAO/WHO for the two metals in vegetables. Plants take up heavy metals by absorbing them from deposits on plants exposed to air from polluted environment as well as from contaminated soils (Al-Jassir *et al*., 2005; Sharma *et al*., 2008a). The intake of heavy metal can lead to altering of humans and animals state of health. Thus, the carcinogenic effects generated by continuous consumption of fruits and vegetables loaded with

heavy metals such as Cd, Pb or even Cu and Zn can lead to the incidence of gastrointestinal cancer (Turkdogan *et al*., 2002) and cancer of the pancreas, urinary bladder or prostate (Waalkes and Rehm, 1994). The subject of heavy metal pollution of the environment is that they can only be transformed from one oxidation state or organic complex to another (Lone *et al*., 2008). Once the environment becomes polluted with Zinc, it begins its journey to man's body (Islam *et al*., 2007; Okoronkwo *et al*., 2005) by being absorbed by plants (Kos *et al*., 2003) which are subsequently consumed by man. The symptoms of high concentration of Zn dose may provoke: Tachycardia, vascular shock, dyspeptic nausea, vomiting, diarrhoea, pancreatitis and damage of hepatic parenchyma (Salgueiro *et al*., 2000).

Lead is a toxic element that can be harmful to plants, although plants normally show its ability to accumulate large amounts of lead without visible changes in their appearance or yield. Lead is a well-known neurotoxin. Impairment of neuro-development in children is the most critical effect. Lead accumulates in the skeleton and its mobility from bones during pregnancy and breastfeeding causes exposure to foetuses and breastfed infants. In many plants, Pb accumulation can exceed several hundred times the threshold of maximum level permissible for human (Wierzbicka, 1995). When Pb is introduced into the food chain humans health can be affected and thus, studies concerning Pb accumulation in vegetables have increasing importance (Coultate, 1992). Lacatusu and Lacatusu (2008) assessed the quality of vegetables and fruits grown within heavy metal polluted environment in Romania. They have found that unlike vegetables, the accumulation of heavy metals in fruits was low because a large proportion of heavy metals absorbed by trees were stored in other organs, especially in leaves. The result of this study compared favorably with this observation as there were lower concentration of heavy metals in okra fruit. The uptake of heavy metals followed this trend Fe > Zn> Pb > Cu >Ni > Cd.

The concentration of the heavy metals were found to be higher in the shoot and root than the fruits. This findings agreed with the result of Sharma *et al.* (2016) who worked on heavy metals in vegetable cultivated with wastewater

Cu is also an essential element but at high concentration causes toxicity and acute exposure of 200 mg/kg can cause death (FAO/WHO, 2011). Arora *et al.* (2008) reported the concentration of Cu in spinach in the range of 15.9- 17.4 mg/kg. in this study, Cu in Okra was (19.2 - 24.3 mg/kg), *Corchorus olitorious* was (5.5 - 19.1 mg/kg), *Amaranthus esculentum* was (33.0-49.3mg/kg) while *Tithonia diversifolia* (12.8 – 36.4mg/kg)) and *Solanum lycopersicon* was (34.5- 41.2mg/kg), only *Corchorus olitorious* (5.5 - 19.1mg/kg) was within the range. This may be because of the high concentration of Cu in the soil used for planting which was collected from the dumpsite. Iron was the most accumulated of all the heavy metals. This finding agreed with Sharma *et al.* (2016) who worked on heavy metals in vegetable cultivated with wastewater. Permissible concentration of Pb in fruit, tuberous and bulb vegetables is 0.1mg/kg, while that in leafy vegetables is 0.3mg/kg (FAO/WHO, 2014). The observed mean concentration in all the crops used in this work was far higher than this as only the *Corchorus olitorious* shoot from the Control soil and Okra fruit on Biochar with dumpsite soil and the Control soil had no Cd. USEPA (2015) identified Cd to affect kidney, Cu and Fe to affect gastrointestinal tract.

The translocation Factor of the heavy metals in the plants grown on the treatment is the quotient of contaminated concentration in shoot to the root , which is used to measure the effectiveness of plant in transferring a pollutant from the root to the shoots (Sun *et al.,*2009). Translocation Factor greater than 1 shows the ability of the plant to translocate heavy metals from the roots to the shoot. Some of the values from this work showed TF> 1 for different metals. Plants with

TF>1 finds it easy to translocate heavy metals from their root to their shoot than those with TF< 1 which restrict the heavy metals to their shoot (Adefemi *et al.,* 2012). Differences in Transfer factor among vegetables may be attributed to differences in the concentration of the heavy metals in the soil and differences in the element uptake by different vegetables (Cui *et al.,* 2004). TF >1 can also be due to efficient metal transporter systems in the plants (Zhao *et al*.,2002) and probably sequestration of metals in leaf vacuoles apoplast (Lasta *et al.,* 2000). The results showed variations in metals accumulation. Accumulation of selected metals varied greatly among plants species and the uptake of element by plant is primarily dependent on plants species, its inherent controls, and the quality of the soil (Chunilall *et al.,* 2005).

The Biological Accumulation Coefficient (BAC) is the ratio of metal concentration in the root to the equivalent concentration in the soil (Ginicchio and Baker, 2004). It was discovered that the values of BAC for Ni in *Amaranthus esculentum, Tithonia diversifolia and Solanum lycopersicon* were significantly higher than the other heavy metals. These results suggested that Ni and Cd had greater accumulation ability in shoots of these plants than the other heavy metals studied. Cd in *C. olitorious, T. diversifolia and S. lycopersicon*, Cu in *C. olitorious* and *S. lycopersicon* with Zn in *T. diversifolia and S. lycopersicon*. This means that all these plants have the ability to accumulate these heavy metals in their roots than in the other parts of the plant.

With this, all the plants used in this work can serve as excluders of Pb and Fe. Based on the BACs, relative efficiency of plants used in this study to absorb metals from heavily contaminated soil could be arranged in the following order: *A. esculentus >T. diversifolia > S. lycopersicon> A. esculentum> Corchorus olitorious.* This is useful in the selection of suitable agricultural

vegetables to be grown on metal contaminated soils. These results also showed that BAC values differed with locations and plant species. The difference in BAC between locations may be related to the plant physiological aspects, soil nutrient management and soil properties.

At present, there are several methods to estimate the potential health risks of pollutants for carcinogenic and non-carcinogenic effects on humans (Iwegbue *et al*., 2015; Storelli *et al.,* 2008; Wang *et al.,* 2009; Zheng *et al.,* 2007). Non-cancer risk assessment is typically based on the Total Health Quotient method (THQ), which is a ratio of the determined dose of a pollutant to the reference oral dose (R_{FD}) (Storelli *et al.,* 2008; S.O.A.E.Q, 2000; Wang *et al.,* 2005). The THQ values are associated with some factors which include intake of pollutants, exposure time, body weight, and reference oral dose of the pollutants. The significant difference in THQ values for adults and children are due to the differences in the intake of metals, exposure time, and body weight. Obvious differences had been found in THQ values in males and females through vegetable consumption in Banat Country, Romania, and THQ values for females were found to be higher than those for males (Harmanescu *et al.*,2011). This indicates that the potential health risks for children were higher than those for adults, and that the potential health risks for females were higher than those for males.

The TTHQ values for females in the current study through vegetable consumption exceeded 1.0, suggesting that the consumers of these vegetables may be facing health risk. Additionally, for special populations, such as those with a weak constitution, those that were sensitive, and women that were pregnant, the potential health risks of heavy metal accumulation through vegetable consumption may likely be higher than for the normal population. However, vegetable consumption was just one part of food consumption. In addition to vegetable consumption, rice

(Zheng *et al.*2007; Hang *et al.,* 2009), meat (Zheng *et al.,* 2007; Bortey-Sam *et al.,*2015), fish (Iwegbue *et al.*,2015), and tobacco (Dong *et al.,* 2015) consumption also led to ingestion of large amounts of heavy metals. Consumption of vegetables raised on waste dumpsites, food consumption, inhalation of soil particles, drinking water, and dermal contact are the important pathways for human exposure to toxic metals (Zhu *et al.,* 2011). The daily intake of a particular element must be below the chronic reference dose of that particular element. Based on the health quotient profile, it is clear that all the heavy metals investigated can have an adverse effect on humans (USEPA, 2010). Consequently, the potential health risks for consumers were actually high from this study. Fortunately, the government and the populace should realize the adverse effects and the significant health risks posed by heavy metals in vegetables and some remediation measures should be taken on contaminated soils to reduce its health risk

Under various conditions, a high temperature causes micropores to widen because it destroys the adjacent pores between the walls, resulting in enlargement of the pores (Zhang et al., 2004). This leads to a decrease in the volume found in the micropore range and an increase in the total pore volume. Zhang *et al*., (2004) found microporosity to be appreciably greater after one hour of physical activation than after two hours in maize hulls and maize stover. They proposed that the rate of pore formation exceeded that of destruction due to pore enlargement and collapse at the earlier stage and vice versa at the later stage (Zhang *et al*., 2004). Heating rates also determine the extent of micropore formation. Cetin *et al*. (2004) found that biochars developed at atmospheric pressure under low heating rates majorly consisted of micropores, whereas those prepared at high heating rates were largely composed of macropores as a result of melting (Cetin *et al*., 2004). Mesopores are also present in biochar materials. These pores are of importance to many liquid-solid adsorption processes. For example, pistachio-nut shells have a mixture of

micropores and mesopores, with micropores dominating, indicating that these activated carbons can be used for both gas and liquid adsorption applications (Lua *et al*., 2004).

Lead (Pb), arsenic (As) and cadmium (Cd) and other metals has been found to be sorb by biochar. A dairy manure biochar made at 350°C absorbed several quantity of Pb than Activated Carbon (Cao *et al*., 2009). In this case, sorption by biochar was attributed mostly (85%) to the Pb reacting with ash present in the biochar, and also to direct surface sorption (15%) on the biochar surfaces. Mohan *et al*., (2007) also worked on the removal of heavy metals in an aqueous solution by biochars made from pine and oak wood and bark at 400-450°C. Due to its greater surface area and pore volume, oak bark biochar absorbed more than all others and removed similar amounts of Pb and Cd from solution as did a commercial AC material (~100% for Pb and ~50% for Cd). Oak bark biochar also removed ~70% of the Pb and Cd in the solution. Other biochars, at pH values in the range of those of most agricultural soils removed ~5-25% Pb, ~0-10% Cd and ~0-10% As from solution. In another study, soil amended with 0.1 and 0.5 % (w/w) pine biochar adsorbed more phenanthrene than in non-amended soil, although the authors found that the amount of this contaminant sorbed by biochar varied with the properties of the biochar, soil characteristics and contact time between biochar and soil (Zhang *et al*., 2010).

Uchimiya *et al*., (2010) found that adding broiler litter biochar to soil enhanced the immobilization of a mixture of Pb, Cd and Ni, and the authors attributed this effect mostly to the rise in pH brought about by the biochar. In a different study, Uchimiya et al., (2010) tested the effect of "natural" organic matter and the biochar unstable carbon fraction on heavy metal immobilization by biochar. They found that these materials improve Cd immobilization by biochar, had no clear effect on immobilization of Ni, and actually led to greater mobility of Cu in

biochar-amended soil with very high pH (>9). Both high-ash and low-ash biochars had the ability to reduce the mobility of Cd, Cu and Ni in the soil, and treating the biochars with phosphoric acid to increase their negative surface charges improved the biochar immobilization capacity.

The presence of porosities on biochars are important to the roots movement through the soil and serve as habitats of different microbes in soil. This is in agreement with Novak et al (2009) which stated that the arrangement of carbon structures were transformed from aliphatics structure to aromatic structure as reported by 13C NMR with the increase of pyrolysis temperature. Pores can be divided into micropores, mesopores and macropores, which have internal diameters of <2 nm, 2-50 nm and >200nm, respectively. In the activated carbon industry, micropores (<2 nm) contribute the vast majority of the surface area and are considered important for adsorption applications. For soil applications, macropores in biochar affect the soil's hydrology and microbial environment. The larger the pores, water, plant roots and fungal hyphae find it easier to penetrate the particle. For smaller microorganisms, pores provide shelter from larger, predatory organisms. Biochars will frequently have specific pore size distributions and arrangements due to maintenance of the plant structure.

This regularly-sized and extensive porosity can be seen in the scanning electron micrographs of biochar shown in Figure 2. Biochar's chemical properties are related to two "carbon fraction" concepts, aromaticity and surface functionality. Aromaticity is defined as the fraction of carbons in char that participate in aromatic bonds. Lignocellulosic feedstocks, which consist of sugar polymers (all aliphatic carbons) and lignin (some aromatic rings), have relatively low aromaticity. As the pyrolysis reaction progresses, oxygen and hydrogen are removed, leaving the remaining carbons to form new aromatic carbon-carbon bonds. The arrangement of the aromatic

carbon sheets changes from random to aligned, stacked sheets resembling graphite at the highest temperatures. The degree of aromatic condensation in biochars is believed to be related to recalcitrance in the environment; carbons in dense aromatic structures are more resistant to oxidation and few microorganisms have enzymes capable of breaking down such bonds. O-H peaks), albeit only qualitatively (Glaser *et al.,* 2001). The particle size decrease observed in the The gasification and fast pyrolysis char is believed decrease the particle size which is believed to be caused by rapid devolatilization creating very porous (macroporous) and fragmented chars (Scala *et al.,* 2006).

The Ph of the biochar produced was between 6.65 and 7.0. This findings agreed with Lehmann (2007), in which biochar was produced with any pH between 4.0 and 12.0 and the pH of fresh biochar tends to increase with an increase in pyrolysis temperature. The biochar of biomass feedstock investigated can be employed as a soil amendment to increase soil pH in acidic soils occupying approximately 30 % of the total arable land on the earth (Yuan *et al*., 2011). A range of 2375 to 2348 cm^{-1} was observed in the FT-IR which was associated with CO_2. The presence of functional groups such as the carboxyl and hydroxyl groups suggest that biochar can be used as a soil amendment for the improvement of cation exchange capacity and as a potential adsorbent. Of all the minerals in the maize cob derived biochar, carbon and oxygen had the highest concentration. This result compared favourably with the composition of C and O, which resulted from the increase in gasification temperature, which increased volatilization of light compounds of raw material and reaction with carbon during gasification, thus reducing the oxygen concentration of char and thus increasing the mineral contents (Quin *et al.,* 2013). The relative small size of peaks observed in this study can be attributed to loss of moisture due to the

high temperatures reached in the pyrolysis process (Kim *et al.*, 2012). Clear peaks are commonly attributed to hemicellulose and cellulose (*i.e.*, 3200-3000 cm^{-1} for OH or 3100-3000 cm^{-1} for CH) were absent in the maize cob derived biochar which may lead one to conclude that the hemicellulose and cellulose present in the raw biomass degenerated at the pyrolysis temperature (Jouiad,*et al.,* 2015). This is an expected result because the degradation of hemicellulose and cellulose generally take place at pyrolysis temperatures between 200-300 ℃ and 300-400 ℃, respectively (Kim *et al* ., 2012). Peaks between 1400 cm^{-1} and 900cm^{-1} are generally attributed to lignin, mainly due to rings of type C=C (Jouiad *et al.*, 2015); These peaks are slightly more pronounced than those found for hemicellulose and cellulose, which can be attributed to the degradation of lignin at temperatures between 200 ℃ and 700 ℃ (Azargohar *et al.*, 2014). The presence of the functional groups such as carboxyl and hydroxyl group suggests that maize cob-derived biochar could be used as a soil amendment to improve the Cation Exchange Capacity of the soil and as an adsorbent (OH *et al* ., 2012)

Conclusion

The results obtained from this work in respect of the analysis of heavy metals in the dumpsite soil and plants have shown that there are far greater concentration of heavy metals in the dumpsite soil than the control soil. Aran-Orin, Offa and Omu-Aran dumpsites were found to be more contaminated/ polluted than other dumpsites. These highly polluted areas are both urban and rural dumpsites. It was observed that irrespective of the location of the dumpsites, the presence of batteries, cans, polyethylene, bottles and other metals can be linked to the high concentration of heavy metals present. Of all the heavy metals analysed Fe had the highest concentration in all the dumpsites. The high concentration of heavy metals in plants from the dumpsites could be attributed to high heavy metal concentration in the soil and also from exhaust from vehicles because most of the dumpsites are located along major roads.

The distribution pattern of heavy metals with respect to distance from the center of the dumpsites showed that distance has no effect on the concentration of heavy metals present in both soil and plant samples. The result obtained showed that the concentration of heavy metals were highest at 20meters away from the center of the dumpsite for most of the dumpsites. The results obtained showed that the concentration of heavy metal did not decrease with increase in the distance from the center of the dumpsite for all the heavy metals analyzed. This may be because most times people do not go to the center of the dumpsite to drop their waste because of the heaps of waste that have been dumped there over-time. It was observed that people drop their waste within the distance range of 20-30meters away from the core of the dumpsites. Another reason for this result may be attributed to erosion because metals deposited at the core of the dumpsites can be easily washed to other parts of the dumpsite. Most times accumulation of dumps over a long

period of time, make the sites to become a hilly terrain making the heavy metals there to be easily washed down after a heavy rainfall to the lowland.

It was also observed that the years that the age of dumpsites may have contributed to the concentration of heavy metals present. For example, Aran-Orin dumpsite has been in existence for more than 50 years, Offa dumpsite has been in existence for more than 20 years and Odo-Ore dumpsite has been in existence for more than 40 years. Long time accumulation of wastes in these dumpsites account for high concentration of heavy metals present..

Nigeria has abundant maize cobs waste which has not been properly managed thereby constituting environmental problem to the populace especially in most rural and semi-urban centres where major occupations are tied to maize processing value chain. On one hand, efforts should be made to reduce the cobs waste through its conversion into useful materials. Hence the need for the production of biochar. A metallic kiln was constructed for this purpose. Biochar application reduced the heavy metals concentration in the dumpsite soil with the effect of boosting the crop physiological growth but the application was noted to have gradually reduced towards the termination of the planting which can be due to the rate at which it was applied (25%). Although, the dramatic increases in plant growth biochar amendments, coupled with no increase in heavy metal accumulation in crop biomass in the field, suggest that the conversion of maize cobs into beneficial biochar is a potential alternative to the current practice of disposal in dwindling landfill space. The heavy metal concentration in the dumpsite soil with biochar remains a problem for land application.

In addition, loading rates utilized in this experiment delivered excess toxicity to the soil beyond some of the established regulatory limits. Despite these drawbacks, the ability of biochar to

reduce heavy metal bioavailability and its ability to enhance plant growth even at a small rate like 1% is enough reason to continue exploring its use as a potentially beneficial soil amendment with a focus on application rates and metal bioavailability at the field scale. Of particular importance of this biochar is the persistence benefits derived over multiple crop cycles with just one application. Biochar application can be reduced to half for maximum yield and also a crop with a long life cycle will be preferred because biochar tends to be more effective when it stays in the soil after the first growing season. The application of Biochar that can immobilize heavy metals could provide a cost-effective and sustainable solution for the remediation of contaminated sites.Since most trees are deep-rooted, they absorb minerals from deep in the soil and a good portion of these minerals go into plants.

Novak *et al*. (2013b) proposed the use of "designer biochars" that is biochar tailored to meet the needs of specific soils. The addition of biochar to soils in agriculture can improve soil fertility, with the added bonus of climate change mitigation through carbon sequestration. Therefore, the use of agricultural waste materials (such as maize cobs) as sole biochar feedstocks is recommended in future trials. Moreover, the agronomic benefits of biochar last longer than those offered by any other forms of organic matter (e.g.manure or compost) commonly applied to land due to it's greater efficiency in retaining nutrients and keeping them available as well as its favorably long persistence in soil (Sa´nchez *et al.*, 2009).

From this study, the concentrations of the heavy metals in crops planted on dumpsite soil showed higher concentration than those on Biochar with dumpsite soil, the biochar application reduced the concentration of the heavy metals. The distribution of the heavy metals in the plants grown

on the treatments differed from plant to plant. The root and shoot of the plants accumulated the heavy metals with the root accumulating more than the shoot. The variation of heavy metal accumulation between the different parts of the plants under study may be useful for selecting suitable vegetable species for cultivation in order to minimize the intake of potentially harmful elements. Hence, the study strongly suggests that water spinach and okra are not recommended to be cultivated in Pb contaminated soils. *Tithonia diversifolia* shoot and *Solanum lycopersicon* had their TF values greater than1, hence makes them potential plants for environmental restoration.

The present study also provided data on the health quotient of consuming crops especially vegetables raised on dumpsite soil in Kwara State. This study has shown that there is greater risk of human exposure to lead (Pb) than other heavy metals studied. The metal which can be hazardous if the vegetables are taken in large quantities. These metals have potentials that are harmful, but the detrimental impact becomes obvious only after decades of exposure. It is therefore suggested that regular monitoring of heavy metals in plant tissues is essential in order to prevent excessive build-up of these metals in the human food chain. Health Quotient (HQ) values through vegetable consumption was 277 for Pb in Okra root, suggesting that consumers (humans and animals) of the vegetable in Ilorin metropolis would face health risks due to the vegetable consumption, and are particularly vulnerable to the adverse effects of ingestion of heavy metals. Pb and Cd were the main elements contributing to potential health risks of vegetable consumption for residents in the study area. The potential health risks of heavy metals through other exposure pathways should be the subject of future study.Serious sensitization of the populace in the area is needed about the health implications of consuming such vegetables.

This study was carried out to provide basic information as to the possibility of the use of biochar derived from different biomass. The experimental results clearly showed that pyrolysis temperature and feedstock type have significant effect on the physico–chemical properties of the biochar. The physical properties of biochar affect many of the functional roles that they may play in environmental management applications. The large variation of physical characteristics observed in different biochar products means that some will be more effective than others in certain applications. Reduction of waste–biomass volume through pyrolysis process also means that the use of biochar may provide possible way to solve the major problem such as management and disposal of the waste biomass. The biochar production from biomass such as maize cob –derived biochar may be an effective way for recycling waste resources. The SEM micrographs revealed a good development of pores in maize cob biochar, thus, the biochar obtained from maize cob is expected to be suitable for absorption applications, even when adsorption capacity could be improved by additional activation processes.

Based on the SEM-EDX analysis, one can conclude that due to the presence of minerals such as K, Si and Mg, biochars could be used as a soil amendment. The carbon content in the maize cob derived biochar was high with high porosity indicating that the carbon content in the biochar can potentially be separated and used as a source for the production of “activated carbon”. Development of porosity increased the specific surface area of biochars while high temperature provides sufficient activation energies for pore creation and enhanced greater degrees of order in the structure. The results showed that temperature significantly influenced the properties of biochars as temperature involves the release of volatiles and formation of intermediate melts.

The increase of temperature reduced the acidic functional groups and conversely increased the basic groups of the biochars. The FT-IR spectra showed the reduction of acidic functional groups

such as phenol, lactonic and carboxylic acid and the existence of basic groups like quinone and carbonyl. These functional groups of pore surface negative charge property contributes to better cation exchange capacity that helps to retain cation nitrogen nutrient compound in soil, such as ammonium (NH_4)

In addition, increase of basic groups also helped to increase the soil pH, especially in improving pH for sandy soil where the pH is below 5.5 and hence improved soil fertility. In conclusion, biochar is a highly potential substance that can be used in many types of soil to improve crop production.

RECOMMENDATION

Based on the findings and observations in this study, the following are made.

(i) Cattle rearing and agricultural farming should be restricted within a radius of 50 meters away from the dumpsite to reduce the health hazards associated with the consumption of edible crops that might have accumulated heavy metals.

(ii) It is recommended that remediation process be put in place to reduce the level of heavy metals below the critical level in order to avert their health hazards that may result in humans that consume vegetables planted on them.

(iii) The use of biochar as soil supplement should be encouraged at lower concentration to reduce the heavy metals concentration in dumpsite soil.

(iv) People should be made to know the adverse effects of heavy metals in vegetables and ways to control and reduce them.

(v) Virtual center for biochar research which combines the skills of agricultural scientists and engineers, material scientists and process engineers, chemists, microbiologists, economists and policy makers should be put in place.

(vi) Education and enlightenment of farmers and the general public on the potential (negative) effects of raising crops on dumpsite soil should be undertaken.

(vii) Methods of reducing wastes and alternative use of maize cobs, which hitherto constituted environmental problem for the people should be encouraged.

(viii) Information on the production of Biochar from maize cobs should be provided locally

(ix) Sensitization on the use of Biochar produced from maize cobs as potential accumulator of heavy metals should be encouraged.

(x) Information on the effectiveness of Biochar on crop yield, and the need to reduce the use of inorganic fertilizer should be passed to the government and the people.

(xi) It is important that the physical characterization of biochars be undertaken before they are experimentally applied to environmental systems, and variations in outcomes may be correlated with these features.

CONTRIBUTION TO KNOWLEDGE

(i) Information on the heavy metals pollution status of dumpsite soil in Kwara State has been provided. It has been established that the soil and the native plants around these dumpsites are polluted with Pb, Cd, Zn, Ni, Cu and Fe. There has not been a study on the pollution status and heavy metals concentrations of these dumpsite before now despite its long years of existence.

(ii) Information has been provided that the distance of a dumpsite to the core does not affect the concentration of heavy metals present there which has not been previously provided.

(iii) This study has provided information that the location of a dumpsite that is either a rural dumpsite or an urban dumpsite does not affect the heavy metals concentrations of the dumpsite but the dumped wastes.

(iv) The age of each dumpsite affects the level of heavy metals concentrations present in them.

(v) Information has been provided on the use of Biochar as soil supplement to reduce heavy metals concentration in the soil from dumpsite and at the same time increasing its productivity.

(vi) It has been established in this study that plants grown on dumpsite soil has the potential of accumulating the heavy metals analysed to levels that are toxic to human and animal's health.

(vii) Information on the health quotient hazard status in Kwara State of the dumpsite soil has been provided to help decision makers (individuals, governments and local community) to take decisions that will be helpful in averting disasters that may be linked to dumpsite pollution and consumption of vegetables.

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APPENDICES

APPENDIX A- ANOVA OF THE DUMPSITE SOIL AT DIFFERENT DISTANCES

1a. Heavy metal concentration of soil from 0m of all urban dumpsite

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	91529884.485	5	18305976.897	58039886.513	.000
Within Groups	3.785	12	.315		
Total	91529888.270	17			

1b. Heavy metal concentration of soil from 10m of all urban dumpsite

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	96907992.354	5	19381598.471	13606589.875	.000
Within Groups	17.093	12	1.424		
Total	96908009.448	17			

1c. Heavy metal concentration of soil from 20m of all urban dumpsite

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	492180383.952	5	98436076.790	156036196.584	.000
Within Groups	7.570	12	.631		
Total	492180391.522	17			

1d. Heavy metal concentration of soil from 30m of all urban dumpsite

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	91405815.868	5	18281163.174	37101725.590	.000
Within Groups	5.913	12	.493		
Total	91405821.781	17			

1e. Heavy metal concentration of soil from 40m of all urban dumpsite

Z	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	180247870.381	5	36049574.076	195002313.905	.000
Within Groups	2.218	12	.185		
Total	180247872.600	17			

APPENDIX II

2a. Heavy metal concentration of soil from 0m of all rural dumpsite

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	45820882.722	5	9164176.544	7409189.870	.000
Within Groups	14.842	12	1.237		
Total	45820897.565	17			

2b. Heavy metal concentration of soil from 10m of all rural dumpsite

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	47943960.369	5	9588792.074	100247.450	.000
Within Groups	1147.815	12	95.651		
Total	47945108.184	17			

2c. Heavy metal concentration of soil from 20m of all rural dumpsite

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	44552514.488	5	8910502.898	11639532.702	.000
Within Groups	9.186	12	.766		
Total	44552523.674	17			

2d. Heavy metal concentration of soil at 30m of all rural dumpsite

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	41013968.534	5	8202793.707	13724408.932	.000
Within Groups	7.172	12	.598		
Total	41013975.706	17			

2e. Heavy metal concentration of soil at 40m of all rural dumpsite

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	274104087.354	5	54820817.471	291654580.754	.000
Within Groups	2.256	12	.188		
Total	274104089.609	17			

Appendix III

Heavy metal concentration of soil samples from the Control sites

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	16761299.167	5	3352259.833	81.201	.000
Within Groups	247701.750	6	412836.625		
Total	17009000.917	11			

Appendix IV

Iv a. Heavy metal concentration of Plants at 0m of all urban dumpsite

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	29096099.023	5	5819219.805	5368095.639	.000
Within Groups	13.008	12	1.084		
Total	29096112.032	17			

Iv b. Heavy metal concentration of Plants at 10m of all urban dumpsite

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	8321831.376	5	1664366.275	1856422.433	.000
Within Groups	10.759	12	.897		
Total	8321842.135	17			

Iv c. Heavy metal concentration of Plants at 20m of all urban dumpsite

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	2390498.241	5	478099.648	399407.387	.000
Within Groups	14.364	12	1.197		
Total	2390512.606	17			

Iv d. Heavy metal concentration of Plants at 30m of all urban dumpsite

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	16780723.220	5	3356144.644	376545.994	.000
Within Groups	106.956	12	8.913		
Total	16780830.175	17			

Iv e. Heavy metal concentration of Plants at 40m of all urban dumpsite

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	3363579.152	5	672715.830	17144.640	.000
Within Groups	470.852	12	39.238		
Total	3364050.004	17			

Appendix V

V a. Heavy metal concentration of Plants at 0m of all rural dumpsite

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	17958593.828	5	3591718.766	6439280.303	.000
Within Groups	6.693	12	.558		
Total	17958600.522	17			

V b. Heavy metal concentration of Plants at 10m of all rural dumpsites

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	4741752.843	5	948350.569	3124910.066	.000
Within Groups	3.642	12	.303		
Total	4741756.485	17			

V c. Heavy metal concentration of Plants at 20m of all rural dumpsite

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	2841223.313	5	568244.663	6122325.079	.000
Within Groups	1.114	12	.093		
Total	2841224.427	17			

V d. Heavy metal concentration of Plants at 30m of all rural dumpsite

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	5741024.871	5	1148204.974	750988.839	.000
Within Groups	18.347	12	1.529		
Total	5741043.218	17			

V e. Heavy metal concentration of Plants at 40m of all rural dumpsite

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	5583517.586	5	1116703.517	1446908.532	.000
Within Groups	9.261	12	.772		
Total	5583526.847	17			

Appendix VI

Heavy metal concentration of Plants samples from Control sites at 0m of all rural dumpsite

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	129622.323	5	25924.465	58.878	.000
Within Groups	2641.865	6	440.311		
Total	132264.189	11			

APPENDIX B POST HOC TESTS

Appendix1a. Heavy metals of soil at 0m of all urban dumpsites

Duncan

ELEMENTS		Subset for alpha = 0.05				
		1	3	4	5	6
Cd	3	.3320				
Ni	3					
Cu	3		6.8320			
Pb	3			9.3310		
Zn	3				251.6663	
Fe	3					6100.0000
Sig.		1.000	1.000	1.000	1.000	1.000

Appendix1b. Heavy metals of soil at 10m of all urban dumpsites

Duncan

ELEMENTS		Subset for alpha = 0.05			
		1	3	4	5
Ni	3	.9444			
Cd	3	1.1666			
Pb	3				
Cu	3		104.1666		
Zn	3			615.1107	
Fe	3				6349.9997
Sig.		.823	1.000	1.000	1.000

Appendix1c. Heavy metals of soil at 20m of all urban dumpsites

Duncan

ELEMENTS	N	Subset for alpha = 0.05				
		1	3	4	5	6
Cd	3	.3332				
Ni	3					
Cu	3		11.4999			
Pb	3			20.9433		
Zn	3				326.6653	
Fe	3					14099.9997
Sig.		1.000	1.000	1.000	1.000	1.000

Appendix1d. Heavy metals of soil at 30m of all urban dumpsites

Duncan

ELEMENTS	N	Subset for alpha = 0.05			
		1	3	4	5
Cd	3	.3333			
Ni	3	.6664			
Pb	3				
Cu	3		6.6667		
Zn	3			183.3330	
Fe	3				6083.3330
Sig.		.572	1.000	1.000	1.000

1e. Heavy metals concentration of soil at 40m of all urban dumpsites

TTYmRural

Duncan

LOCATION	N	Subset for alpha = 0.05			
		1	2	3	4
Cd	3	.5000			
Ni	3	.6662			
Pb	3		2.5000		
Cu	3		3.6664		
Zn	3			181.9997	
Fe	3				4255.6663
Sig.		.820	.128	1.000	1.000

TRTYmRural

Duncan

LOCATION	N	Subset for alpha = 0.05			
		1	2	3	4
Cd	3	.3332			
Ni	3	1.0000			
Cu	3		6.1666		
Pb	3		6.4666		
Zn	3			255.0000	
Fe	3				4096.6663
Sig.		.312	.643	1.000	1.000

FOURTYmRural

Duncan

LOCATION	N	Subset for alpha = 0.05				
		1	2	3	5	6
Cd	3	1.6664				
Ni	3		6.8333			
Cu	3			9.8333		
Pb	3					
Zn	3				396.6662	
Fe	3					
Sig.		1.000	1.000	1.000	1.000	

a

Control

Duncan

LOCATION	N	Subset for alpha = 0.0	
		1	2
Ni	2	.2500	
Cd	2	.5000	
Pb	2	1.0000	
Cu	2	2.5000	
Zn	2	158.2500	
Fe	2		
Sig.		.483	

APPENDIX C: ANOVA of growth parameters of crops

Appendix I:Growth parameters of Okra at 2WAP

		Sum of Squares	df	Mean Square	F	Sig.
Shoot Height	Between Groups	10.609	3	3.536	2.134	.174
	Within Groups	13.260	8	1.658		
	Total	23.869	11			
Number of Leaves	Between Groups	3.000	3	1.000	12.000	.002
	Within Groups	.667	8	.083		
	Total	3.667	11			
Leaf Length	Between Groups	3.996	3	1.332	14.938	.001
	Within Groups	.713	8	.089		
	Total	4.709	11			
Leaf breadth	Between Groups	2.903	3	.968	38.700	.000
	Within Groups	.200	8	.025		
	Total	3.103	11			
Leaf Area	Between Groups	50.491	3	16.830	20.823	.000
	Within Groups	6.466	8	.808		
	Total	56.957	11			
Petiole Lenght	Between Groups	56.537	3	18.846	1.103	.403
	Within Groups	136.720	8	17.090		
	Total	193.257	11			

Appendix II. Growth parameters of Okra at 4WAP

		Sum of Squares	df	Mean Square	F	Sig.
	Between Groups	.889	3	.296	.037	.990
Shoot Height	Within Groups	63.300	8	7.913		
	Total	64.189	11			
	Between Groups	6.000	3	2.000	8.000	.009
Number Of Leaves	Within Groups	2.000	8	.250		
	Total	8.000	11			
	Between Groups	6.049	3	2.016	3.351	.076
Leaf Lenght	Within Groups	4.813	8	.602		
	Total	10.863	11			
	Between Groups	5.469	3	1.823	6.077	.019
Leaf Breadth	Within Groups	2.400	8	.300		
	Total	7.869	11			
	Between Groups	163.358	3	54.453	4.210	.046
Leaf Area	Within Groups	103.478	8	12.935		
	Total	266.837	11			
	Between Groups	5.056	3	1.685	12.110	.002
Petiole Lenght	Within Groups	1.113	8	.139		
	Total	6.169	11			

Appendix III. Growth parameters of Okra at 6WAP

		Sum of Squares	Df	Mean Square	F	Sig.
	Between Groups	74.947	3	24.982	4.135	.048
Shoot Height	Within Groups	48.333	8	6.042		
	Total	123.280	11			
	Between Groups	1.667	3	.556	1.333	.330
Number Of Leaves	Within Groups	3.333	8	.417		
	Total	5.000	11			
	Between Groups	5.190	3	1.730	3.507	.069
Leaf Lenght	Within Groups	3.947	8	.493		
	Total	9.137	11			
	Between Groups	1.420	3	.473	.778	.538
Leaf Breadth	Within Groups	4.867	8	.608		
	Total	6.287	11			
	Between Groups	95.072	3	31.691	1.966	.198
Leaf Area	Within Groups	128.978	8	16.122		
	Total	224.049	11			
	Between Groups	7.789	3	2.596	51.928	.000
Petiole Lenght	Within Groups	.400	8	.050		
	Total	8.189	11			
	Between Groups	3.333	3	1.111	6.667	.014
Number Of Fruit	Within Groups	1.333	8	.167		
	Total	4.667	11			
	Between Groups	8.790	3	2.930	1.137	.391
Fresh Weight Of Plant	Within Groups	20.607	8	2.576		
	Total	29.397	11			
	Between Groups	.929	3	.310	1.352	.325
Dry Weight Of Plant	Within Groups	1.833	8	.229		
	Total	2.763	11			
	Between Groups	37.103	3	12.368	24.093	.000
Fresh Weight Of Fruit	Within Groups	4.107	8	.513		
	Total	41.209	11			
	Between Groups	1.102	3	.367	44.100	.000
Dry Weight Of Fruit	Within Groups	.067	8	.008		
	Total	1.169	11			

Appendix IV. Growth parameters of *Cochorus olitorus* at 2WAP

		Sum of Squares	Df	Mean Square	F	Sig.
Shoot Height	Between Groups	19.167	3	6.389	6.143	.018
	Within Groups	8.320	8	1.040		
	Total	27.487	11			
Number Of Leaves	Between Groups	2.000	3	.667	.667	.596
	Within Groups	8.000	8	1.000		
	Total	10.000	11			
Leaf Lenght	Between Groups	3.109	3	1.036	2.115	.177
	Within Groups	3.920	8	.490		
	Total	7.029	11			
Leaf Breadth	Between Groups	.683	3	.228	2.152	.172
	Within Groups	.847	8	.106		
	Total	1.530	11			
Leaf Area	Between Groups	3.795	3	1.265	2.858	.104
	Within Groups	3.541	8	.443		
	Total	7.336	11			
Petiole Lenght	Between Groups	.337	3	.112	4.489	.040
	Within Groups	.200	8	.025		
	Total	.537	11			

Appendix V. Growth parameters of *Cochorus olitorus* at 4WAP

		Sum of Squares	Df	Mean Square	F	Sig.
Shoot Height	Between Groups	65.797	3	21.932	10.154	.004
	Within Groups	17.280	8	2.160		
	Total	83.077	11			
Number Of Leaves	Between Groups	81.000	3	27.000	15.429	.001
	Within Groups	14.000	8	1.750		
	Total	95.000	11			
Leaf Lenght	Between Groups	10.789	3	3.596	8.429	.007
	Within Groups	3.413	8	.427		
	Total	14.202	11			
Leaf Breadth	Between Groups	.709	3	.236	1.904	.207
	Within Groups	.993	8	.124		
	Total	1.702	11			
Leaf Area	Between Groups	18.900	3	6.300	4.644	.037
	Within Groups	10.853	8	1.357		
	Total	29.753	11			
Petiole Lenght	Between Groups	2.269	3	.756	5.971	.019
	Within Groups	1.013	8	.127		
	Total	3.283	11			

Appendix VI. Growth parameters of *Cochorus olitorus* at 6WAP

		Sum of Squares	Df	Mean Square	F	Sig.
	Between Groups	6603.583	3	2201.194	1.412	.309
Shoot Height	Within Groups	12473.993	8	1559.249		
	Total	19077.577	11			
	Between Groups	514.917	3	171.639	2.584	.126
Number Of Leaves	Within Groups	531.333	8	66.417		
	Total	1046.250	11			
	Between Groups	7.102	3	2.367	3.199	.084
Leaf Lenght	Within Groups	5.920	8	.740		
	Total	13.022	11			
	Between Groups	.863	3	.288	2.031	.188
Leaf Breadth	Within Groups	1.133	8	.142		
	Total	1.997	11			
	Between Groups	21.167	3	7.056	2.725	.114
Leaf Area	Within Groups	20.713	8	2.589		
	Total	41.881	11			
	Between Groups	1.427	3	.476	8.646	.007
Petiole Lenght	Within Groups	.440	8	.055		
	Total	1.867	11			
	Between Groups	.516	3	.172	.066	.977
Fresh Weight of Plant	Within Groups	20.907	8	2.613		
	Total	21.423	11			
	Between Groups	.270	3	.090	.437	.732
Dry Weight of Plant	Within Groups	1.647	8	.206		
	Total	1.917	11			

Appendix VII. Growth parameters of *Amaranthus esculentus* at 2WAP

		Sum of Squares	Df	Mean Square	F	Sig.
Shoot Height	Between Groups	63.443	3	21.148	488.019	.000
	Within Groups	.347	8	.043		
	Total	63.789	11			
Number Of Leaves	Between Groups	104.250	3	34.750	.	.
	Within Groups	.000	8	.000		
	Total	104.250	11			
Leaf Lenght	Between Groups	8.857	3	2.952	136.256	.000
	Within Groups	.173	8	.022		
	Total	9.030	11			
Leaf Breadth	Between Groups	2.836	3	.945	43.628	.000
	Within Groups	.173	8	.022		
	Total	3.009	11			
Leaf Area	Between Groups	73.875	3	24.625	21.047	.000
	Within Groups	9.360	8	1.170		
	Total	83.235	11			
Petiole Lenght	Between Groups	.967	3	.322	193.333	.000
	Within Groups	.013	8	.002		
	Total	.980	11			

Appendix VIII. Growth parameters of *Amaranthus esculentus* at 4WAP

		Sum of Squares	Df	Mean Square	F	Sig.
Shoot Height	Between Groups	65.302	3	21.767	1.933	.203
	Within Groups	90.067	8	11.258		
	Total	155.369	11			
Number Of Leaves	Between Groups	30.917	3	10.306	5.889	.020
	Within Groups	14.000	8	1.750		
	Total	44.917	11			
Leaf Lenght	Between Groups	9.862	3	3.287	2.907	.101
	Within Groups	9.047	8	1.131		
	Total	18.909	11			
Leaf Breadth	Between Groups	2.543	3	.848	3.767	.059
	Within Groups	1.800	8	.225		
	Total	4.343	11			
Leaf Area	Between Groups	66.115	3	22.038	2.262	.158
	Within Groups	77.954	8	9.744		
	Total	144.069	11			
Petiole Length	Between Groups	.710	3	.237	3.595	.066
	Within Groups	.527	8	.066		
	Total	1.237	11			

Appendix IX. Growth parameters of *Amaranthus esculentus* at 6WAP

		Sum of Squares	Df	Mean Square	F	Sig.
Shoot Height	Between Groups	41.300	3	13.767	.654	.603
	Within Groups	168.387	8	21.048		
	Total	209.687	11			
Number Of Leaves	Between Groups	44.250	3	14.750	3.052	.092
	Within Groups	38.667	8	4.833		
	Total	82.917	11			
Leaf Length	Between Groups	7.156	3	2.385	1.591	.266
	Within Groups	11.993	8	1.499		
	Total	19.149	11			
Leaf Breadth	Between Groups	1.953	3	.651	2.141	.173
	Within Groups	2.433	8	.304		
	Total	4.387	11			
Leaf Area	Between Groups	120.226	3	40.075	2.089	.180
	Within Groups	153.454	8	19.182		
	Total	273.680	11			
Petiole Length	Between Groups	1.983	3	.661	1.983	.195
	Within Groups	2.667	8	.333		
	Total	4.650	11			
Fresh Weight of Plant	Between Groups	97.133	3	32.378	1.797	.226
	Within Groups	144.167	8	18.021		
	Total	241.300	11			
Dry Weight of Plant	Between Groups	3.449	3	1.150	2.204	.165
	Within Groups	4.173	8	.522		
	Total	7.623	11			

Appendix X. Growth parameters of *Tithonia diversifolias* at 2WAP

	N	Subset for alpha = 0.05
		1
Biochar with Control soil	3	10.9000
Biochar with Dumpsite Soil	3	12.6000
Dumpsite Soil	3	14.6667
Control Soil	3	15.7000
Sig.		.262

Duncan

TITHONIA AT 6wap

ANOVA

		Sum of Squares	Df	Mean Square	F	Sig.
ShootHeight	Between Groups	14.670	3	4.890	1.396	.313
	Within Groups	28.027	8	3.503		
	Total	42.697	11			
NumberOfLeaves	Between Groups	5.333	3	1.778	.163	.918
	Within Groups	87.333	8	10.917		
	Total	92.667	11			
LeafLenght	Between Groups	9.300	3	3.100	9.588	.005
	Within Groups	2.587	8	.323		
	Total	11.887	11			
LeafBreadth	Between Groups	3.389	3	1.130	10.117	.004
	Within Groups	.893	8	.112		
	Total	4.283	11			
LeafArea	Between Groups	329.042	3	109.681	26.332	.000
	Within Groups	33.322	8	4.165		
	Total	362.365	11			
PetioleLenght	Between Groups	1.043	3	.348	3.794	.058
	Within Groups	.733	8	.092		
	Total	1.777	11			

Tithonia at 8wap

ANOVA

		Sum of Squares	Df	Mean Square	F	Sig.
ShootHeight	Between Groups	47.070	3	15.690	4.980	.031
	Within Groups	25.207	8	3.151		
	Total	72.277	11			
NumberOfLeaves	Between Groups	76.917	3	25.639	10.256	.004
	Within Groups	20.000	8	2.500		
	Total	96.917	11			
LeafLenght	Between Groups	3.417	3	1.139	6.156	.018
	Within Groups	1.480	8	.185		
	Total	4.897	11			
LeafBreadth	Between Groups	4.603	3	1.534	23.913	.000
	Within Groups	.513	8	.064		
	Total	5.117	11			
LeafArea	Between Groups	243.966	3	81.322	20.872	.000
	Within Groups	31.170	8	3.896		
	Total	275.136	11			
PetioleLenght	Between Groups	1.163	3	.388	3.941	.054
	Within Groups	.787	8	.098		
	Total	1.949	11			
FreshWeight	Between Groups	50.220	3	16.740	2.366	.147
	Within Groups	56.607	8	7.076		
	Total	106.827	11			
DryWeight	Between Groups	4.353	3	1.451	2.366	.147
	Within Groups	4.907	8	.613		
	Total	9.260	11			

Tomato 4WAP

ANOVA

		Sum of Squares	Df	Mean Square	F	Sig.
ShootHeight	Between Groups	5.417	3	1.806	4.359	.043
	Within Groups	3.313	8	.414		
	Total	8.730	11			
NumberOfLeaves	Between Groups	40.000	3	13.333	3.265	.080
	Within Groups	32.667	8	4.083		
	Total	72.667	11			
LeafLenght	Between Groups	3.149	3	1.050	8.569	.007
	Within Groups	.980	8	.122		
	Total	4.129	11			
LeafBreadth	Between Groups	1.073	3	.358	6.314	.017
	Within Groups	.453	8	.057		
	Total	1.527	11			
LeafArea	Between Groups	7.270	3	2.423	8.836	.006
	Within Groups	2.194	8	.274		
	Total	9.464	11			
PetioleLenght	Between Groups	1.690	3	.563	52.000	.000
	Within Groups	.087	8	.011		
	Total	1.777	11			

10wap

ANOVA

		Sum of Squares	Df	Mean Square	F	Sig.
ShootHeight	Between Groups	126.457	3	42.152	4.843	.033
	Within Groups	69.633	8	8.704		
	Total	196.090	11			
NumberOfLeaves	Between Groups	2475.583	3	825.194	1.406	.310
	Within Groups	4694.667	8	586.833		
	Total	7170.250	11			
LeafLenght	Between Groups	.582	3	.194	1.752	.234
	Within Groups	.887	8	.111		
	Total	1.469	11			
LeafBreadth	Between Groups	.120	3	.040	.500	.693
	Within Groups	.640	8	.080		
	Total	.760	11			
LeafArea	Between Groups	4.342	3	1.447	3.688	.062
	Within Groups	3.140	8	.392		
	Total	7.481	11			
PetioleLenght	Between Groups	1.169	3	.390	2.362	.147
	Within Groups	1.320	8	.165		
	Total	2.489	11			

Appendix XIIf. Petiole Length of *Tithonia diversifolia* at 6WAP

Duncan

TithoniaatTwoWAP	N	Subset for alpha = 0.05	
		1	2
Control Soil	3	1.1667	
Biochar with Control soil	3	1.4000	1.4000
Biochar with Dumpsite Soil	3	1.4000	1.4000
Dumpsite Soil	3		1.9667
Sig.		.392	.059

Appendix XIIIa. Shoot Height of *Tithonia diversifolia* at 8WAP

Duncan

TithoniaatTwoWAP	N	Subset for alpha = 0.05	
		1	2
Biochar with Dumpsite Soil	3	11.3333	
Biochar with Control soil	3	13.6333	13.6333
Control Soil	3		15.2333
Dumpsite Soil	3		16.6667
Sig.		.151	.080

Appendix XIIIb. Number Of Leaves of *Tithonia diversifolia* at 8WAP

Duncan

TithoniaatTwoWAP	N	Subset for alpha = 0.05	
		1	2
Biochar with Dumpsite Soil	3	10.0000	
Dumpsite Soil	3	11.3333	
Biochar with Control soil	3		14.6667
Control Soil	3		16.3333
Sig.		.332	.233

Appendix XIIIc. Leaf Length of *Tithonia diversifolia* at 8WAP

Duncan

TithoniaatTwoWAP	N	Subset for alpha = 0.05	
		1	2
Biochar with Control soil	3	5.9667	
Biochar with Dumpsite Soil	3	6.1333	
Control Soil	3	6.1333	
Dumpsite Soil	3		7.3000
Sig.		.661	1.000

Appendix XIIId. Leaf Breadth of *Tithonia diversifolia* at 8WAP

Duncan

TithoniaatTwoWAP	N	Subset for alpha = 0.05		
		1	2	3
Biochar with Control soil	3	2.5333		
Biochar with Dumpsite Soil	3	2.9000	2.9000	
Control Soil	3		3.2333	
Dumpsite Soil	3			4.2000
Sig.		.114	.146	1.000

Appendix XIIIe. Leaf Area of *Tithonia diversifolia* at 8WAP

Duncan

TithoniaatTwoWAP	N	Subset for alpha = 0.05	
		1	2
Biochar with Control soil	3	11.3867	
Biochar with Dumpsite Soil	3	13.3667	
Control Soil	3	14.9100	
Dumpsite Soil	3		23.2267
Sig.		.069	1.000

Appendix XIIIf. Petiole Length of *Tithonia diversifolia* at 8WAP

Duncan

TithoniaatTwoWAP	N	Subset for alpha = 0.05	
		1	2
Control Soil	3	1.5333	
Biochar with Dumpsite Soil	3	1.6333	
Dumpsite Soil	3	1.7333	
Biochar with Control soil	3		2.3333
Sig.		.475	1.000

Appendix XIIIg. Fresh Weight of *Tithonia diversifolia* at 8WAP

Duncan

TithoniaatTwoWAP	N	Subset for alpha = 0.05
		1
Biochar with Control soil	3	5.7333
Control Soil	3	6.1333
Biochar with Dumpsite Soil	3	6.6333
Dumpsite Soil	3	10.8333
Sig.		.059

Appendix XIIIh. Dry Weight of *Tithonia diversifolia* at 8WAP

Duncan

TithoniaatTwoWAP	N	Subset for alpha = 0.05
		1
Biochar with Dumpsite Soil	3	1.0333
Control Soil	3	1.1667
Biochar with Control soil	3	1.2667
Dumpsite Soil	3	2.5333
Sig.		.059

Appendix XVIa. Shoot Height of *Solanum lycopersicon* at 6WAP

Duncan

Tomatoes	N	Subset for alpha = 0.05	
		1	2
Biochar with Control soil	3	6.0000	
Biochar with Dumpsite Soil	3	8.3667	8.3667
Control Soil	3		10.0000
Dumpsite Soil	3		10.6333
Sig.		.125	.154

Appendix XVIb. Number Of Leaves of *Solanum lycopersicon* at 6WAP

Duncan

Tomatoes	N	Subset for alpha = 0.05	
		1	2
Biochar with Dumpsite Soil	3	19.6667	
Biochar with Control soil	3	25.3333	25.3333
Control Soil	3		33.0000
Dumpsite Soil	3		36.0000
Sig.		.269	.064

Appendix XVIc. Leaf Length of *Solanum lycopersicon* at 6WAP

Duncan

Tomatoes	N	Subset for alpha = 0.05
		1
Biochar with Control soil	3	1.7667
Biochar with Dumpsite Soil	3	1.9000
Control Soil	3	2.5000
Dumpsite Soil	3	2.5667
Sig.		.144

Appendix XVId. Leaf Breadth of *Solanum lycopersicon* at 6WAP

Duncan

Tomatoes	N	Subset for alpha = 0.05
		1
Biochar with Dumpsite Soil	3	1.0000
Biochar with Control soil	3	1.1000
Control Soil	3	1.3667
Dumpsite Soil	3	1.4333
Sig.		.221

Appendix XVIe. Leaf Area of *Solanum lycopersicon* at 6WAP

Duncan

Tomatoes	N	Subset for alpha = 0.05
		1
Biochar with Dumpsite Soil	3	1.4267
Biochar with Control soil	3	1.4867
Dumpsite Soil	3	2.8067
Control Soil	3	2.8800
Sig.		.231

Appendix XVIf. Petiole Length of *Solanum lycopersicon* at 6WAP

Duncan

Tomatoes	N	Subset for alpha = 0.05	
		1	2
Biochar with Control soil	3	1.3000	
Biochar with Dumpsite Soil	3	1.6000	1.6000
Control Soil	3	1.6667	1.6667
Dumpsite Soil	3		2.1667
Sig.		.265	.101

Appendix XVIIa. Shoot height of ***Solanum lycopersicon*** **at 8WAP**

Duncan

Tomatoes	N	Subset for alpha = 0.05	
		1	2
Biochar with Control soil	3	12.5000	
Biochar with Dumpsite Soil	3	12.8000	
Control Soil	3		20.0000
Dumpsite Soil	3		22.2333
Sig.		.878	.273

Appendix XVIIb. Number Of Leaves of *Solanum lycopersicon* at 8WAP

Duncan

Tomatoes	N	Subset for alpha = 0.05		
		1	2	3
Biochar with Control soil	3	27.0000		
Biochar with Dumpsite Soil	3		49.6667	
Dumpsite Soil	3			65.3333
Control Soil	3			71.3333
Sig.		1.000	1.000	.360

Appendix XVIIc. Leaf Length of *Solanum lycopersicon* at 8WAP

Duncan

Tomatoes	N	Subset for alpha = 0.05	
		1	2
Biochar with Control soil	3	2.0000	
Control Soil	3	2.1000	
Biochar with Dumpsite Soil	3	2.5667	2.5667
Dumpsite Soil	3		2.8000
Sig.		.055	.364

Appendix XVIId. Leaf Breadth of *Solanum lycopersicon* at 8WAP

Duncan

Tomatoes	N	Subset for alpha = 0.05	
		1	2
Control Soil	3	1.0000	
Biochar with Control soil	3	1.1000	1.1000
Biochar with Dumpsite Soil	3	1.3000	1.3000
Dumpsite Soil	3		1.5000
Sig.		.171	.080

Appendix XVIIe. Leaf Area of *Solanum lycopersicon* at 8WAP

Duncan

Tomatoes	N	Subset for alpha = 0.05	
		1	2
Control Soil	3	1.5567	
Biochar with Control soil	3	1.6500	
Biochar with Dumpsite Soil	3	2.5300	2.5300
Dumpsite Soil	3		3.1833
Sig.		.112	.246

Appendix XVIIf. Petiole Length of *Solanum lycopersicon* at 8WAP

Duncan

Tomatoes	N	Subset for alpha = 0.05	
		1	2
Biochar with Control soil	3	1.5000	
Biochar with Dumpsite Soil	3	1.8667	1.8667
Control Soil	3	2.1000	2.1000
Dumpsite Soil	3		2.5000
Sig.		.150	.131

Appendix XXa. Shoot Height of *Solanum lycopersicon* at 14WAP

Duncan

Tomatoes	N	Subset for alpha = 0.05	
		1	2
Control Soil	3	27.4000	
Biochar with Control soil	3	30.0000	30.0000
Biochar with Dumpsite Soil	3	31.3667	31.3667
Dumpsite Soil	3		40.6333
Sig.		.451	.067

Appendix XXb. Number Of Leaves of *Solanum lycopersicon* at 14WAP

Duncan

Tomatoes	N	Subset for alpha = 0.05	
		1	2
Biochar with Dumpsite Soil	3	80.6667	
Control Soil	3	91.6667	91.6667
Biochar with Control soil	3		144.0000
Dumpsite Soil	3		146.6667
Sig.		.646	.051

Appendix XXc. Leaf Length of *Solanum lycopersicon* at 14WAP

Duncan

Tomatoes	N	Subset for alpha = 0.05	
		1	2
Dumpsite Soil	3	2.7000	
Biochar with Control soil	3	2.9000	
Control Soil	3	2.9333	
Biochar with Dumpsite Soil	3		3.6333
Sig.		.440	1.000

Appendix XXd. Leaf Breadth of *Solanum lycopersicon* at 14WAP

Duncan

Tomatoes	N	Subset for alpha = 0.05	
		1	2
Biochar with Control soil	3	1.4000	
Dumpsite Soil	3	1.5667	1.5667
Control Soil	3	1.6000	1.6000
Biochar with Dumpsite Soil	3		1.9000
Sig.		.349	.136

Appendix XXe. Leaf Area of *Solanum lycopersicon* at 14WAP

Duncan

Tomatoes	N	Subset for alpha = 0.05	
		1	2
Biochar with Control soil	3	3.0500	
Dumpsite Soil	3	3.2200	
Control Soil	3	3.5867	
Biochar with Dumpsite Soil	3		5.1700
Sig.		.473	1.000

Appendix XXf. Petiole Length of *Solanum lycopersicon* at 14WAP

Duncan

Tomatoes	N	Subset for alpha = 0.05		
		1	2	3
Control Soil	3	1.6000		
Dumpsite Soil	3	2.2667	2.2667	
Biochar with Dumpsite Soil	3		2.8667	2.8667
Biochar with Control soil	3			3.5000
Sig.		.086	.116	.100

Appendix XXg. Fresh Weight Of Plant of *Solanum lycopersicon* at 14WAP

Duncan

Tomatoes	N	Subset for alpha = 0.05
		1
Control Soil	3	6.4667
Dumpsite Soil	3	8.8767
Biochar with Dumpsite Soil	3	8.9333
Biochar with Control soil	3	11.3000
Sig.		.086

Appendix XXh. Dry Weight Of Plant of *Solanum lycopersicon* at 14WAP

Duncan

Tomatoes	N	Subset for alpha = 0.05	
		1	2
Biochar with Dumpsite Soil	3	1.5667	
Dumpsite Soil	3	2.0333	
Control Soil	3	2.3000	2.3000
Biochar with Control soil	3		2.9667
Sig.		.097	.113

Appendix Xxi. Fresh Weight Of Fruits of *Solanum lycopersicon* at 14WAP

Duncan

Tomatoes	N	Subset for alpha = 0.05			
		1	2	3	4
Biochar with Dumpsite Soil	3	.0000			
Control Soil	3		.6000		
Biochar with Control soil	3			1.4667	
Dumpsite Soil	3				1.8000
Sig.		1.000	1.000	1.000	1.000

APPENDIX E POST HOC TESTS

Appendix E i a. Cd concentration in Okra shoot

Duncan

OKRA	N	Subset for alpha = 0.05		
		1	2	3
Control soil	3	.8233		
Biochar with control soil	3	.8733		
Biochar with dumpsite soil	3		2.3637	
Dumpsite soil	3			2.7790
Sig.		.407	1.000	1.000

Appendix E i b. Pb concentration in Okra shoot

Duncan

OKRA	N	Subset for alpha = 0.05			
		1	2	3	4
Control soil	3	13.5933			
Biochar with control soil	3		15.1200		
Biochar with dumpsite soil	3			16.8333	
Dumpsite soil	3				25.0333
Sig.		1.000	1.000	1.000	1.000

Appendix E i c. Ni concentration in Okra shoot

Duncan

OKRA	N	Subset for alpha = 0.05		
		1	2	3
Biochar with dumpsite soil	3	7.2800		
Biochar with control soil	3	7.2900		
Dumpsite soil	3		11.4467	
Control soil	3			12.3433
Sig.		.853	1.000	1.000

Appendix E i d. Fe concentration in Okra shoot

Duncan

OKRA	N	Subset for alpha = 0.05			
		1	2	3	4
Biochar with dumpsite soil	3	418.7133			
Biochar with control soil	3		497.2033		
Control soil	3			986.3333	
Dumpsite soil	3				1002.3003
Sig.		1.000	1.000	1.000	1.000

Appendix E i e. Cu concentration in Okra shoot

Duncan

OKRA	N	Subset for alpha = 0.05			
		1	2	3	4
Biochar with dumpsite soil	3	19.2937			
Control soil	3		21.3200		
Biochar with control soil	3			21.5600	
Dumpsite soil	3				24.2167
Sig.		1.000	1.000	1.000	1.000

Appendix E i f. Zn concentration in Okra shoot

Duncan

OKRA	N	Subset for alpha = 0.05			
		1	2	3	4
Control soil	3	110.1167			
Biochar with dumpsite soil	3		178.3527		
Dumpsite soil	3			178.8233	
Biochar with control soil	3				180.4300
Sig.		1.000	1.000	1.000	1.000

Appendix E ii a. Cd concentration in Okra Root

Duncan

OKRA ROOT	N	Subset for alpha = 0.05			
		1	2	3	4
Control soil	3	1.1350			
Biochar with control soil	3		1.8000		
Biochar with dumpsite soil	3			2.4900	
Dumpsite soil	3				3.0700
Sig.		1.000	1.000	1.000	1.000

Appendix E ii b. Pb concentration in Okra Root

Duncan

OKRA ROOT	N	Subset for alpha = 0.05			
		1	2	3	4
Biochar with control soil	3	27.1927			
Control soil	3		27.7433		
Biochar with dumpsite soil	3			136.7167	
Dumpsite soil	3				499.6000
Sig.		1.000	1.000	1.000	1.000

Appendix E ii c. Ni concentration in Okra Root

Duncan

OKRASHOOT	N	Subset for alpha = 0.05	
		1	2
Biochar with control soil	3	7.8333	
Dumpsite soil	3	11.3347	11.3347
Biochar with dumpsite soil	3	11.6667	11.6667
Control soil	3		21.7700
Sig.		.525	.108

Appendix E ii d. Fe concentration in Okra Root

Duncan

OKRA ROOT	N	Subset for alpha = 0.05			
		1	2	3	4
Control soil	3	3156.4767			
Dumpsite soil	3		4350.9810		
Biochar with dumpsite soil	3			4546.2167	
Biochar with control soil	3				6764.5000
Sig.		1.000	1.000	1.000	1.000

Appendix E ii e. Cu concentration in Okra Root

Duncan

OKRASHOOT	N	Subset for alpha = 0.05			
		1	2	3	4
Biochar with control soil	3	3.6567			
Control soil	3		51.5215		
Biochar with dumpsite soil	3			302.6507	
Dumpsite soil	3				824.1850
Sig.		1.000	1.000	1.000	1.000

Appendix E ii f. Zn concentration in Okra Root

Duncan

OKRA ROOT	N	Subset for alpha = 0.05			
		1	2	3	4
Dumpsite soil	3	59.1600			
Control soil	3		110.4533		
Biochar with control soil	3			221.1000	
Biochar with dumpsite soil	3				576.1733
Sig.		1.000	1.000	1.000	1.000

Appendix E iii a. Cd concentration in *Cochorus olitorious* shoot

Duncan

COCHORUS SHOOT	N	Subset for alpha = 0.05	
		1	2
Biochar with dumpsite soil	3	.9000	
Control soil	3	.9100	
Biochar with control soil	3	.9333	
Dumpsite soil	3		2.2333
Sig.		.825	1.000

Appendix E iii b. Pb concentration in *Cochorus olitorious* shoot

Duncan

COCHORUS SHOOT	N	Subset for alpha = 0.05		
		1	2	3
Control soil	3	.0000		
Biochar with control soil	3		5.2033	
Biochar with dumpsite soil	3		5.2967	
Dumpsite soil	3			54.1000
Sig.		1.000	.841	1.000

Appendix Eiii c. Ni concentration in *Cochorus olitorious* shoot

Duncan

OKRAFRUIT	N	Subset for alpha = 0.05	
		1	2
Biochar with dumpsite soil	3	.0000	
Biochar with control soil	3	.0000	
Dumpsite soil	3		3.6467
Control soil	3		5.1033
Sig.		1.000	.294

Appendix E iii d. Fe concentration in *Cochorus olitorious* shoot

Duncan

COCHORUSSHOOT	N	Subset for alpha = 0.05			
		1	2	3	4
Biochar with dumpsite soil	3	112.3000			
Biochar with control soil	3		167.3213		
Control soil	3			232.3867	
Dumpsite soil	3				319.0000
Sig.		1.000	1.000	1.000	1.000

Appendix E iii e. Cu concentration in *Cochorus olitorious* shoot

COCHORUS SHOOT	N	Subset for alpha = 0.05			
		1	2	3	4
Biochar with dumpsite soil	3	5.5800			
Biochar with control soil	3		6.9267		
Control soil	3			14.0633	
Dumpsite soil	3				18.8333
Sig.		1.000	1.000	1.000	1.000

Appendix E iii f. Zn concentration in *Cochorus olitorious* shoot

Duncan

COCHORUSSHOOT	N	Subset for alpha = 0.05		
		1	2	3
Control soil	3	51.4400		
Biochar with dumpsite soil	3	51.7667		
Biochar with control soil	3		56.8700	
Dumpsite soil	3			151.2000
Sig.		.687	1.000	1.000

Appendix E iv a. Cd concentration in *Cochorus olitorious* Root

	N	Subset for alpha = 0.05			
		1	2	3	4
Control soil	3	.8987			
Biochar with control soil	3		1.3500		
Biochar with dumpsite soil	3			3.2333	
Dumpsite soil	3				4.8300
Sig.		1.000	1.000	1.000	1.000

Appendix E iv b. Pb concentration in *Cochorus olitorious* Root

Duncan

COCHORUS ROOT	N	Subset for alpha = 0.05		
		1	2	3
Control soil	3	27.4333		
Biochar with dumpsite soil	3	29.2667	29.2667	
Biochar with control soil	3		32.0200	
Dumpsite soil	3			53.6067
Sig.		.186	.061	1.000

Appendix E iv c. Ni concentration in *Cochorus olitorious* Root

Duncan

COCHORUS ROOT	N	Subset for alpha = 0.05			
		1	2	3	4
Biochar with control soil	3	12.2833			
Dumpsite soil	3		15.6567		
Control soil	3			18.1600	
Biochar with dumpsite soil	3				21.7000
Sig.		1.000	1.000	1.000	1.000

Appendix E iv d. Fe concentration in *Cochorus olitorious* Root

Duncan

COCHORUS ROOT	N	Subset for alpha = 0.05			
		1	2	3	4
Biochar with dumpsite soil	3	8092.7200			
Control soil	3		9708.3133		
Dumpsite soil	3			9945.2237	
Biochar with control soil	3				10991.3267
Sig.		1.000	1.000	1.000	1.000

Appendix E iv e. Cu concentration in *Cochorus olitorious* Root

Duncan

COCHORUS ROOT	N	Subset for alpha = 0.05			
		1	2	3	4
Biochar with control soil	3	40.8883			
Control soil	3		66.9133		
Biochar with dumpsite soil	3			506.2500	
Dumpsite soil	3				1643.7333
Sig.		1.000	1.000	1.000	1.000

Appendix E iv f. Zn concentration in *Cochorus olitorious* Root

Duncan

COCHORUS ROOT	N	Subset for alpha = 0.05			
		1	2	3	4
Control soil	3	118.4567			
Biochar with control soil	3		155.1600		
Biochar with dumpsite soil	3			593.3467	
Dumpsite soil	3				782.5917
Sig.		1.000	1.000	1.000	1.000

Appendix E v a. Cd concentration in *Amaranthus esculentus* shoot

Duncan

AMARANTHUS Shoot	N	Subset for alpha = 0.05
		1
Biochar with control soil	3	2.2433
Dumpsite soil	3	2.2900
Biochar with dumpsite soil	3	2.3467
Control soil	3	2.3933
Sig.		.345

Appendix E v b. Pb concentration in *Amaranthus esculentus shoot*

Duncan

AMARANTHUS Shoot	N	Subset for alpha = 0.05			
		1	2	3	4
Biochar with dumpsite soil	3	3.1427			
Dumpsite soil	3		18.0133		
Biochar with control soil	3			27.6733	
Control soil	3				40.0900
Sig.		1.000	1.000	1.000	1.000

Appendix E v c. Ni concentration in *Amaranthus esculentus shoot*

Duncan

AMARANTHUS Shoot	N	Subset for alpha = 0.05			
		1	2	3	4
Dumpsite soil	3	12.2667			
Biochar with control soil	3		13.4633		
Biochar with dumpsite soil	3			40.3927	
Control soil	3				172.2433
Sig.		1.000	1.000	1.000	1.000

Appendix E v d. Fe concentration in *Amaranthus esculentus shoot*

Duncan

AMARANTHUS Shoot	N	Subset for alpha = 0.05			
		1	2	3	4
Dumpsite soil	3	496.4333			
Biochar with dumpsite soil	3		828.6333		
Biochar with control soil	3			956.5067	
Control soil	3				1836.2167
Sig.		1.000	1.000	1.000	1.000

Appendix E v e. Cu concentration in *Amaranthus esculentus shoot*

Duncan

AMARANTHUS Shoot	N	Subset for alpha = 0.05			
		1	2	3	4
Control soil	3	30.8700			
Biochar with control soil	3		33.0800		
Biochar with dumpsite soil	3			35.9533	
Dumpsite soil	3				49.1500
Sig.		1.000	1.000	1.000	1.000

Appendix E v f. Zn concentration in *Amaranthus esculentus shoot*

Duncan

AMARANTHUS Shoot	N	Subset for alpha = 0.05			
		1	2	3	4
Control soil	3	130.8067			
Biochar with control soil	3		134.2967		
Biochar with dumpsite soil	3			243.8500	
Dumpsite soil	3				267.9933
Sig.		1.000	1.000	1.000	1.000

Appendix E vi a. Cd concentration in *Amaranthus esculentus Root*

Duncan

AMARANTHUS ROOT	N	Subset for alpha = 0.05			
		1	2	3	4
Control soil	3	.9533			
Dumpsite soil	3		1.1567		
Biochar with control soil	3			2.3333	
Biochar with dumpsite soil	3				3.0300
Sig.		1.000	1.000	1.000	1.000

Appendix E vi b. Pb concentration in *Amaranthus esculentus Root*

Duncan

AMARANTHUS ROOT	N	Subset for alpha = 0.05			
		1	2	3	4
Biochar with control soil	3	22.1667			
Control soil	3		39.8667		
Biochar with dumpsite soil	3			95.3067	
Dumpsite soil	3				350.8033
Sig.		1.000	1.000	1.000	1.000

Appendix E vi c. Ni concentration in *Amaranthus esculentus Root*

Duncan

AMARANTHUS ROOT	N	Subset for alpha = 0.05			
		1	2	3	4
Biochar with control soil	3	14.4667			
Dumpsite soil	3		20.8967		
Control soil	3			63.7767	
Biochar with dumpsite soil	3				87.0600
Sig.		1.000	1.000	1.000	1.000

Appendix E vi d. Fe concentration in *Amaranthus esculentus Root*

Duncan

AMARANTHUS ROOT	N	Subset for alpha = 0.05			
		1	2	3	4
Biochar with dumpsite soil	3	1027.2333			
Biochar with control soil	3		6240.6667		
Control soil	3			6599.2983	
Dumpsite soil	3				11635.3733
Sig.		1.000	1.000	1.000	1.000

Appendix E vi e. Cu concentration in *Amaranthus esculentus Root*

Duncan

AMARANTHUS ROOT	N	Subset for alpha = 0.05			
		1	2	3	4
Biochar with control soil	3	25.7467			
Control soil	3		31.4867		
Biochar with dumpsite soil	3			109.9967	
Dumpsite soil	3				817.9433
Sig.		1.000	1.000	1.000	1.000

Appendix E vi f. Zn concentration in *Amaranthus esculentus Root*

Duncan

AMARANTHUS ROOT	N	Subset for alpha = 0.05			
		1	2	3	4
Biochar with control soil	3	34.2967			
Control soil	3		61.5400		
Biochar with dumpsite soil	3			180.7900	
Dumpsite soil	3				643.7120
Sig.		1.000	1.000	1.000	1.000

Appendix E vii a. Cd concentration in *Tithonia diversifolia Shoot*

Duncan

TITHONIA SHOOT	N	Subset for alpha = 0.05			
		1	2	3	4
Biochar with control soil	3	.9667			
Control soil	3		2.3133		
Biochar with dumpsite soil	3			3.6667	
Dumpsite soil	3				5.2000
Sig.		1.000	1.000	1.000	1.000

Appendix E vii b. Pb concentration in *Tithonia diversifolia Shoot*

Duncan

TITHONIA SHOOT	N	Subset for alpha = 0.05
		1
Biochar with dumpsite soil	3	39.2800
Biochar with control soil	3	39.9533
Dumpsite soil	3	40.1933
Control soil	3	40.3833
Sig.		.073

Appendix E vii c. Ni concentration in *Tithonia diversifolia Shoot*

Duncan

TITHONIA SHOOT	N	Subset for alpha = 0.05			
		1	2	3	4
Control soil	3	8.5600			
Biochar with dumpsite soil	3		24.3000		
Biochar with control soil	3			31.7000	
Dumpsite soil	3				42.2000
Sig.		1.000	1.000	1.000	1.000

Appendix E vii d. Fe concentration in *Tithonia diversifolia Shoot*

Duncan

TITHONIA SHOOT	N	Subset for alpha = 0.05			
		1	2	3	4
Control soil	3	647.5000			
Biochar with dumpsite soil	3		712.0933		
Biochar with control soil	3			740.1000	
Dumpsite soil	3				999.9000
Sig.		1.000	1.000	1.000	1.000

Appendix E vii e. Cu concentration in *Tithonia diversifolia Shoot*

Duncan

TITHONIA SHOOT	N	Subset for alpha = 0.05			
		1	2	3	4
Dumpsite soil	3	12.6000			
Biochar with control soil	3		16.8333		
Control soil	3			21.2633	
Biochar with dumpsite soil	3				34.7333
Sig.		1.000	1.000	1.000	1.000

Appendix E vii f. Zn concentration in *Tithonia diversifolia Shoot*

Duncan

TITHONIA SHOOT	N	Subset for alpha = 0.05			
		1	2	3	4
Biochar with control soil	3	75.3667			
Control soil	3		99.7733		
Biochar with dumpsite soil	3			147.3000	
Dumpsite soil	3				151.7533
Sig.		1.000	1.000	1.000	1.000

Appendix E viii a. Cd concentration in *Tithonia diversifolia Root*

Duncan

TITHONIA ROOT	N	Subset for alpha = 0.05			
		1	2	3	4
Biochar with control soil	3	1.7000			
Control soil	3		2.3567		
Biochar with dumpsite soil	3			3.4667	
Dumpsite soil	3				4.4933
Sig.		1.000	1.000	1.000	1.000

Appendix E viii b. Pb concentration in *Tithonia diversifolia Root*

Duncan

TITHONIA ROOT	N	Subset for alpha = 0.05			
		1	2	3	4
Biochar with control soil	3	40.5667			
Control soil	3		50.1433		
Biochar with dumpsite soil	3			137.3333	
Dumpsite soil	3				508.9167
Sig.		1.000	1.000	1.000	1.000

Appendix E viii c. Ni concentration in *Tithonia diversifolia Root*

Duncan

TITHONIA ROOT	N	Subset for alpha = 0.05			
		1	2	3	4
Biochar with dumpsite soil	3	14.2667			
Control soil	3		23.1500		
Biochar with control soil	3			23.8533	
Dumpsite soil	3				743.7900
Sig.		1.000	1.000	1.000	1.000

Appendix E viii d. Fe concentration in *Tithonia diversifolia Root*

Duncan

TITHONIA ROOT	N	Subset for alpha = 0.05			
		1	2	3	4
Biochar with dumpsite soil	3	3400.4333			
Control soil	3		4957.6067		
Dumpsite soil	3			6696.0867	
Biochar with control soil	3				7002.9333
Sig.		1.000	1.000	1.000	1.000

Appendix E viii e. Cu concentration in *Tithonia diversifolia Root*

Duncan

TITHONIA ROOT	N	Subset for alpha = 0.05		
		1	2	3
Biochar with control soil	3	34.9667		
Control soil	3	40.9333		
Biochar with dumpsite soil	3		205.8667	
Dumpsite soil	3			713.6533
Sig.		.464	1.000	1.000

Appendix E viii f. Zn concentration in *Tithonia diversifolia Root*

Duncan

TITHONIA ROOT	N	Subset for alpha = 0.05			
		1	2	3	4
Control soil	3	69.1900			
Biochar with control soil	3		91.7633		
Biochar with dumpsite soil	3			267.3800	
Dumpsite soil	3				1264.8733
Sig.		1.000	1.000	1.000	1.000

Appendix E ix a. Fe concentration in *Solanum lycopersicon shoot*

Duncan

TOMATO SHOOT	N	Subset for alpha = 0.05		
		1	2	3
Dumpsite soil	3	508.1767		
Biochar with dumpsite soil	3	508.9667		
Biochar with control soil	3		602.7600	
Control soil	3			695.5833
Sig.		.619	1.000	1.000

Appendix E ix b. Cu concentration in *Solanum lycopersicon shoot*

Duncan

TOMATOSHOOT	N	Subset for alpha = 0.05		
		1	2	3
Control soil	3	35.1000		
Biochar with control soil	3		38.9000	
Biochar with dumpsite soil	3			40.5000
Dumpsite soil	3			41.1600
Sig.		1.000	1.000	.138

Appendix E ix c. Zn concentration in *Solanum lycopersicon shoot*

Duncan

TOMATO SHOOT	N	Subset for alpha = 0.05			
		1	2	3	4
Biochar with control soil	3	8.0000			
Control soil	3		79.7700		
Biochar with dumpsite soil	3			289.6100	
Dumpsite soil	3				308.5667
Sig.		1.000	1.000	1.000	1.000

Appendix E x a. Fe concentration in *Solanum lycopersicon Root*

Duncan

TOMATO ROOT	N	Subset for alpha = 0.05			
		1	2	3	4
Biochar with control soil	3	495.1933			
Control soil	3		878.1000		
Biochar with dumpsite soil	3			7170.8300	
Dumpsite soil	3				10248.9000
Sig.		1.000	1.000	1.000	1.000

Appendix E x b. Cu concentration in *Solanum lycopersicon Root*

Duncan

TOMATO ROOT	N	Subset for alpha = 0.05			
		1	2	3	4
Control soil	3	11.3067			
Biochar with control soil	3		19.7067		
Biochar with dumpsite soil	3			1029.5567	
Dumpsite soil	3				1041.0000
Sig.		1.000	1.000	1.000	1.000

Appendix E x c. Zn concentration in *Solanum lycopersicon Root*

Duncan

TOMATO ROOT	N	Subset for alpha = 0.05			
		1	2	3	4
Biochar with control soil	3	22.7267			
Control soil	3		129.3067		
Biochar with dumpsite soil	3			1153.2233	
Dumpsite soil	3				1310.0667
Sig.		1.000	1.000	1.000	1.000

Appendix E xi a. Cd concentration in *Abelmoschus esculentum fruit*

Duncan

OKRA FRUIT	N	Subset for alpha = 0.05		
		1	2	3
Control soil	3	1.6467		
Biochar with control soil	3	1.7133		
Dumpsite soil	3		2.3367	
Biochar with dumpsite soil	3			2.5200
Sig.		.336	1.000	1.000

Appendix E xi b. Pb concentration in *Abelmoschus esculentum fruit*

Duncan

OKRA FRUIT	N	Subset for alpha = 0.05		
		1	2	3
Biochar with dumpsite soil	3	.0000		
Control soil	3	.0000		
Biochar with control soil	3		21.0633	
Dumpsite soil	3			22.1667
Sig.		1.000	1.000	1.000

Appendix E xi c. Ni concentration in *Abelmoschus esculentum fruit*

Duncan

OKRA FRUIT	N	Subset for alpha = 0.05		
		1	2	3
Biochar with dumpsite soil	3	11.0767		
Biochar with control soil	3		14.2533	
Dumpsite soil	3		14.4667	
Control soil	3			15.2667
Sig.		1.000	.192	1.000

Appendix E xi d. Fe concentration in *Abelmoschus esculentum fruit*

Duncan

OKRA FRUIT	N	Subset for alpha = 0.05		
		1	2	3
Control soil	3	220.6933		
Biochar with dumpsite soil	3	221.6267		
Biochar with control soil	3		258.6297	
Dumpsite soil	3			338.8333
Sig.		.454	1.000	1.000

Appendix E xi e. Cu concentration in *Abelmoschus esculentum fruit*

Duncan

OKRA FRUIT	N	Subset for alpha = 0.05			
		1	2	3	4
Biochar with control soil	3	10.8333			
Biochar with dumpsite soil	3		13.0987		
Control soil	3			16.4600	
Dumpsite soil	3				18.4333
Sig.		1.000	1.000	1.000	1.000

Appendix E xi f. Zn concentration in *Abelmoschus esculentum fruit*

Duncan

OKRAFRUIT	N	Subset for alpha = 0.05			
		1	2	3	4
Dumpsite soil	3	70.1000			
Biochar with dumpsite soil	3		73.7433		
Biochar with control soil	3			82.1867	
Control soil	3				110.1967
Sig.		1.000	1.000	1.000	1.000

Hazard Quotient of some plants in different soil treatment

Plant	Treatment	Cd	Pb	Ni	Fe	Cu	Zn
Abelmoschus esculentum Shoot	DS	6.18	13.91	1.27	3.18	1.35	1.32
	BD	5.25	9.35	0.81	1.33	1.07	1.32
	CS	1.83	7.55	1.37	3.13	1.18	0.82
	BC	1.94	8.40	0.81	1.58	1.20	1.34
Abelmoschus esculentum root	DS	6.80	277.56	1.26	13.81	45.79	0.44
	BD	5.53	75.93	1.30	14.43	54.48	4.27
	CS	2.52	15.41	2.42	10.02	2.86	0.82
	BC	4.00	15.11	0.87	21.47	0.20	1.64
Corchorus olitorious Shoot	DS	4.96	30.05	0.41	1.01	1.05	1.12
	BD	1.96	2.94	0.00	0.36	0.31	0.38
	CS	2.02	0.00	0.57	0.74	0.78	0.38
	BC	2.07	2.89	0.00	0.50	0.38	0.42
Corchorus olitorious root	DS	10.73	29.78	1.74	31.57	91.32	5.80
	BD	7.19	16.26	2.41	25.69	28.13	4.42
	CS	2.00	15.24	2.02	30.82	3.72	0.88
	BC	3.00	17.79	1.36	34.89	2.27	1.15
Amaranthus esculentus Shoot	DS	5.09	10.01	1.36	1.58	2.73	1.99
	BD	5.21	1.75	4.49	2.63	1.20	1.81
	CS	5.32	22.27	19.14	5.83	1.72	0.97
	BC	4.99	15.37	1.50	3.04	1.84	0.99
Amaranthus esculentus Root	DS	2.57	194.89	2.32	36.94	45.44	4.77
	BD	6.73	52.95	9.67	3.26	6.11	10.04
	CS	2.12	22.15	7.09	20.95	1.75	0.46
	BC	5.11	12.31	1.61	10.81	1.43	0.25
Tithonia dIversifolia Shoot	DS	11.56	22.33	4.69	3.17	0.70	1.12
	BD	8.15	21.82	2.7	2.26	1.93	1.09
	CS	5.14	22.44	0.95	2.06	1.18	0.74
	BC	2.15	22.20	3.53	2.35	0.94	0.56

Tithonia dIversifolia Root	DS	9.99	282.73	82.64	21.26	39.64	9.37
	BD	7.70	76.28	1.59	10.80	11.44	1.98
	CS	5.24	27.86	2.57	15.74	2.27	0.51
	BC	3.78	22.54	2.65	22.23	1.94	0.68
Solanum lycopersicon Shoot	DS	7.91	21.94	8.34	1.61	2.29	2.29
	BD	5.4	12.11	1.66	1.62	2.25	2.15
	CS	ND	ND	ND	2.21	1.95	0.59
	BC	ND	ND	ND	1.91	2.16	0.06
Solanum lycopersicon Root	DS	10.50	340.94	17.48	32.54	261.01	9.70
	BD	10.22	183.87	2.58	22.76	57.83	8.54
	CS	ND	ND	ND	2.79	57.20	0.96
	BC	5.14	4.04	1.58	1.57	0.63	0.17
Abelmoschus esculentum Fruit	DS	5.19	12.31	1.63	1.08	1.02	0.52
	BD	5.6	0.00	1.23	0.70	0.73	0.55
	CS	3.66	0.00	1.70	0.70	0.91	0.82
	BC	3.81	11.70	1.58	0.82	0.60	0.61

DS - Dumpsite Soil
BD – Biochar with Dumpsite soil
CS – Control Soil

BC – Biochar with Control soil

ND- Not Detected