ASSESSMENT OF THE ENVIRONMENTAL AND HEALTH IMPACTOF PERI-URBAN VEGETABLE FARMING IN SELECTED AREAS OF OSUN STATE, NIGERIA

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DEDICATION

This research work is dedicated to the loving memory of my late parents, PaDavid and Mrs. RoselineOlaniyan. The memories of your virtues, values and training you laboured so much to give me have seen me this far and will remain ever fresh.

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ABSTRACT

This study identified various sources of water used for irrigation in selected peri-urban farms and assessed the agronomic practices associated with peri-urban farming in selected areas of Osun State, Nigeria. It also investigated chemical properties of the soil,

heavy metals in soil and vegetable samples collected from the study areas as well as the soil pollution load. These were with a view to providing information on the potential health risk associated with human consumption of peri-urban vegetables.

Fifteen peri-urban farmers were purposively selectedwithin seven cities in Osun State and structured questionnaire administered through face-to-face interview. Additional information gathered during the field survey included farming practices adopted by the selected farmers and sources of farm input. Soil (30) and vegetable (60) samples were also collected from the selected peri-urban farms between January-April (a dry weather season, when irrigation was at its peak). A control experiment was set up at the greenhouse of Faculty of Agriculture, ObafemiAwolowo University, Ile-Ife. Chemical parameters (pH, Organic Carbon, Organic Matter and NO_3^-) and heavy metals (As, Cd, Cu, Pb, Zn) concentrations in the soil and edible portions of vegetables (*Amaranthushybridus and Corchorusolitorius*) were quantitatively determined using standard methods. Appropriate descriptive and inferential statistical methods were adopted for data analyses.

The results showed that 67% of the farmers irrigated their farms with nearby streams, 7% with shallow well, 13% with river tributaries and 13% with waste water. About 93% of the farmers carried out weeding by hand pulling while 7% applied herbicides. Sixty percent of the farmers maintained soil fertility by applying inorganic fertilizer, 13% applied both poultry manure and inorganic fertilizers while the remaining 27% depended on nature fertility.Nitrate ion concentration in soil and vegetable samples varied between 20.45-240.52 mg/kg and 214.15-1204.52 mg/kg respectively. Concentration of heavy metals in the soils ranged: 0.18-0.63, 2.40-56.17, 0.70-36.75 and 30-300 mg/kg for Cd, Cu, Pb and Zn, respectively. Heavy metals concentration in vegetable samples varied between 0.10-0.83, 0.85-10.45, 0.06-11.55 and 14.12-11.55 mg/kg for Cd, Cu, Pb and Zn, respectively. The pollution load indexfor Cd, Cu, Pb and Zn ranged: 1.51-5.25, 0.86-11.34, 0.15-8.02 and 0.44-6.49, respectively. The transfer factor of Cd, Cu, Pb and Zn ranged: 0.07-4.44, 0.06-0.41, 0.07-4.28 and 0.31-4.08 mg/kg, respectively for *A.hybridus*, and 0.11-2.11, 0.06-2.27, 0.06-3.86 and 0.13-2.63 mg/kg, respectively for *C.olitorius*. The estimated daily intake of Cd, Cu,Pb and Zn from consumption of *A.hybridus*ranged between 0.0003-0.001, 0.00021-0.016, 0.002-0.014 and 0.053-0.159 mg/kg/day, respectively and 0.0002-0.0016, 0.004-0.016, 0.0017-0.0076 and 0.023-0.144 mg/kg/day, respectively for consumption of *C. olitorius*. Health risk index for Cd, Cu,Pb and Zn from consumption of *A. hybridus* ranged between 0.30-1.20, 0.03-0.38, 0.10-4.75 and 0.18-0.86, respectively and 0.20-0.90, 0.10-0.43, 0.35-1.68 and 0.08-0.48, respectively for consumption of *C.olitorius*.

The study concluded that vegetables from selected peri-urban farms werenot safe for consumption and might pose possible health hazard to humans due to the high heavy metals content.

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Agriculture is often associated with rural areas, even though it has been practiced in urban and peri-urban areas since ancient times in backyards, on roof tops and road sides, in vacant plots and un-constructed areas, on river and lake beds and in other small land lots.Peri-urban agriculture refers to farm units close to towns which operate intensive semi- or fully-commercial farms to grow vegetables and other horticultural crops, raise chickens and other livestock, and produce milk and eggs (Stephanie *et al*., 2006). Peri-urbanagriculture occurs within and surrounding the boundaries of cities throughout the world and includes products from crop and livestock agriculture, fisheries and forestry. The territory included within official city boundaries varies enormously across countries and can be more or less built-up, densely to sparsely populated. The distinction between "urban" and "peri-urban" depends on the density, types, and patterns of land use, which determine the constraints and opportunities for agriculture (Mukundi *et al*., 2014). What these diverse activities have in common and in some cases what sets them apart from rural agriculture is proximity to large settlements of people, thereby creating opportunities as well as risks.

Peri-urban agriculture reduces food insecurity by providing direct access to home-produced food to households and to the informal market (Van Leeuwen, 2001; Hillel, 2001). Much of peri-urban agriculture is for own consumption with occasional surpluses sold into the local market. Even for people who have little or no land, part-time farming of vegetables can provide food and income(Agbonlahor *et al.*,2007).Peri-urbanagriculture also enhances food security during times of crisis and severe scarcity (Nwauwa and Omonona, 2010)whether caused by national crises (civil war, widespread drought, currency devaluations, inability to import, etc.) or household crises (illness, health, sudden unemployment, etc.). Peri-urban farming plays an important role in providing emergency supplies of food(Akuffo and Irene, 2013),enhancing the freshness of perishable foods reaching urban consumers, thereby increasing overall variety and the nutritional value of food available. An important reason appears to be that food produced by consumers or in close proximity to them is often fresher than food that travels long distance to markets.

Peri-urban agriculture offers opportunities for productive employment in a sector with low barriers to entry. Over 800 million urban residents worldwideare estimated to be involved in food-producing activity (UNDP, 1996; FAO, 1999). Peri-urban agriculture is often carried out on a part-time basis by women, who can combine food production activity with child care and other household responsibilities. Peri-urban producers achieve real efficiencies by making productive use of under-utilized resourcessuch as vacant land, treated wastewater and recycled waste, and unemployed labour(Abdulai, 2006). Productivity can be as much as 15 times the output per acre of rural agriculture; however, yields often suffer from inferior or insufficient inputs, use of poorly adapted varieties, poor water management, and lack of farming knowledge.

Horticultural production has expanded in and around cities in many developing countries as an informal activity practiced by poor and landless city dwellers. The broad diversity of horticultural crop species allows year-round production, employment and income (Akinmoladun and Adejumo, 2011). Growers have realized that intensive horticulture can be practiced on small plots, making efficient use of limited water and land resources. Horticultural species, as opposed to other food crops, have a considerable yield potential and can provide up to 50 kg of fresh produce per m^2 per year depending upon the technology applied. In addition, due to their short cycle they provide a quick response to emergency needs for food (several species can be harvested 60 to 90 days after planting.) Leafy vegetables provide a quick return to meet a family's daily cash requirements for purchasing food. Leafy vegetables are particularly perishable and post-harvest losses can be reduced significantly when production is located close to consumers.

Vegetable production is done mainly during the rainy season in Southwestern Nigeria. During this season, vegetables are easy to grow as water is available and farmers can avoid the cost of irrigation (Olasantan, 1996).Vegetable production is one of the most important enterprises of peri-urban production systems in Nigeria because vegetables are an important component of human diet and they can be easily cultivated on small areas (Ojo *et al*., 2011). Whereas, the Food and Agricultural Organization of the United Nations (FAO) and the World Health Organization (WHO) recommended a daily vegetable intake of 200 g per person, the NigerianNationalaverage is below this value (Kintomo*et al*., 1997). This inadequate intake of fresh vegetables may further be worsened during the dry season when moisture scarcity limits the area under cultivation and quantity of vegetables that can be grown and supplied to the urban areas. On the other hand, a previous study by Kintomo*et al.*(1997) in Ibadan indicated that it was more profitable to grow vegetables during the dry season than in rainy season. Growing vegetables during this period also leads to higher quality produce because of low disease pressures and pest infestation compared to vegetables grown under rain-fed conditions.In that study however, 81% of farmers rated water management and/or poor drainage system as the most important abiotic constraint limiting dry season vegetable production.

The risks from agricultural production systems in peri-urban areas to health and environment canarise from the inappropriate or excessive use of agricultural inputs (especially pesticides, inorganic fertilizers, raw organic matter containing undesirable residues such as heavy metals) that may leach or runoff into drinking water sources; air pollution (e.g. carbon dioxide and methane from organic matter, ammonia, nitrous oxide and nitrogen oxide from nitrates); and odour nuisance (Khai *et al*., 2007; de Neergaard *et al.*, 2009). In particular, produce (especially leafy vegetables) can be contaminated by heavy metals through overuse of agrochemical sprays. Although none of these problems are specific to peri-urban production as they also result from inappropriate management in rural areas, the potential negative impact is greater in urban settings due to space limitation (Senouci *et al.*, 1993; Albrecht *et al*., 1995). Furthermore, while peri-urban agriculture consists of small production units that may not present problems individually, and thus are not subject to controls or environmental restrictions, they can create substantial problems through cumulative effects.

Peri-urban farming and the agronomic practices associated with it is a widespread activity around the world and there is a growing body of knowledge on peri-urban farms contaminated with heavy metals while the effects of heavy metals on human health are well documented (Liu *et al.*,2005; Mapanda *et al*., 2005; Rattan *et al*., 2005; Rothenberg *et al*., 2007; Ojo *et al.,* 2010; Khaled and Muhammed, 2016). Additional insights into metal uptake and accumulation in relation to the potential human health risks associated with peri-urban vegetable farming is still needed.

1.2 Statement of Research Problem

Farming within and around urban centres (peri-urban farming) is a major source of fresh crop produce, notably vegetables. However, the limitation of land resources and the associated high level of soil contamination from domestic and industrial pollutants are major concerns for the safety of food materials from peri-urban farming. Reported excessive accumulation of heavy metals by food crops from agricultural soils coupled with dearth of empirical data regarding heavy metals accumulation through peri-urban farming activities are major sources of concern, hence this study.

1.3 Objectives of Study

Objectives of this study were to:

a. identify sources of water used in peri-urban farms of selected areas in Osun State;
b. assess the appropriateness of agronomic practices in selected peri-urban farms;
c. investigate the soil chemical properties as well as pollution load of selected peri-urban farms;
d. assess uptake of selected metals by vegetables; and
e. assess the potential health risks associated with human consumption of peri-urban vegetables.

CHAPTER TWO

LITERATURE REVIEW

2.1 Peri-urban Farming

Peri-urban agricultural sector is an agricultural productionsystem together with pre- and post-production support services within the immediate surroundings of cities (Mohammed and Folorunsho, 2015). Commercial peri-urban vegetable productions are usually located within peripheral zones near major urban conglomerates. These zones form a belt of varying radii with market-oriented intensive vegetable production often affected by, or causing, environmental hazards (Richter *et al*., 1995). The volume and diversity of demand for food stimulated the need for increased agricultural production around vicinity of cities. The inability of rural farmers to cope with food demand of urban population generated interest in promoting the development of peri-urban practices. Economic needs and knowledge of peri-urban farming has transformed the left over land from urbanization into farms dominated by short cycle crops. The farms are developed to satisfy desire to generate household income, improve family nutrition, contribute to employment generation and poverty reduction.

World-wide, some 800 million persons are believed to be involved in someform of peri-urban agriculture (Smit *et al*., 1996). It isoften assumed that the profitability and sustainability of peri-urban agriculture ingeneral, and that of vegetable production in particular, is virtually guaranteed by thenearby existence of large populations, relatively low transportation and packagingcosts and low post-harvest losses. Enhanced peri-urban farm income would providethe base for investment in value-adding and other high return activities in peri-urbanareas while contributing to overall economic growth (Goletti *et al*., 1999; Boncodin, 2000).

Urban populationworldwide is growing at twice the rate of total populationgrowth (World Bank, 2000), creating unprecedented demands for goods and servicesas well as increasing pressure on the environment. The importance, characteristics and potential of peri-urbanagriculturein developing countries has received due recognition only recently. Vegetable commodities in particular have receivedincreasing attention since they are highly perishable, and when cool chains are rareor incomplete as in much of the developing world, are often produced close to wherethey will be consumed. Hence, "Vegetable production has thus becomeconcentrated in peri-urban zones where there exist large urban populations and highincome elasticities of demand" (Jansen, 1992).Example from China demonstrates dramatic shifts in occupationsand incomes of peri-urban communities (Jansen and Midmore, 1995).There arehigher income and employmentopportunities amongst peri-urban producers of vegetables than their rice-producingcounterpartswhich havebeen sufficient to compete with urban demands for labour.Over a 15-year period, a complete shift of land use has taken place away from rice cultivation toa predominately vegetable production system and from an agricultural to a non-agricultural dominated work force. On average, financial returns for vegetable production were greater than for cereal production but also much more variable.Financial solvency of peri-urban farms is not only an issue to developing countries,but in developed countries too.Nugent (2000) argued that intensive peri-urban vegetable production can utilize an under-employed work force, but this is not so where less arduous and better paidemployment is available in industry. Increasing costs for hired labour could result in production of some peri-urban vegetable crops becoming less competitivethan those rurally grown(Rosegrant and Hazell, 2000).

The argument that peri-urban vegetable production systems can absorb significantquantities of city waste is supported by experiences from Vietnam and the Philippines (Jansen and Midmore, 1995),and to a lesser extent, Ghana and Burkina Faso (Dittoh *et al*., 2013).Peri-urban vegetable production systems offer potential solutions to municipalgoverrnments faced with insurmountable issues of waste management and disposal.Jansen *et al*. (1996) estimated that peri-urban vegetable production could assimilate

665,000 tonnes oforganic wastes per year. Average waste production per capita in low-income countriesis consistently estimated at 150 kg/year (Medina, 1993; Simpson, 1993).In developingcountries however, the use of 'true' composted urban wastes is scarce and instead,urban organic wastes are frequently used as a'compost' input (a euphemism for city waste, including sewage) to peri-urban horticulture, which is also a source ofwaste (sewage) water for irrigation (Allison and Harris, 1996). Unlike chemical fertilizer,the use of various forms of urban waste has the potential to help preventsoil degradation and erosion by adding organic matter to the soil, and closes themineral nutrient cycle (Midmore, 1995).

Most peri-urban agricultural operations in general and peri-urban vegetable production in particular, face rather poor prospects.There is pressure from various competing land uses within theurban environment.Another key concern of peri-urban agriculture is the risk of pathogen and heavy metal contamination toconsumers due to the high dependency of production systems on the large amount of cheaplyavailable organic wastes and waste water materials (Khai*et al*., 2007; de Neergaard*et al*.,2009) and lack of a clear policy regarding the practice and planned management of urbanagriculture in most African cities (Ezedinma and Chukuezi, 1999; Olofin and Tanko, 2003;Wakuru and Drescher, 2008). In thelong run unless promotive policies and improved technologies become available andfarmers get compensated for the positive externalities generated by their production activities, negative externalities of peri-urban farming might be imposed on the society.

2.2 Water Use for Peri-urban Farming

Water is one of the most important inputs essential for crop production. It profoundly influences photosynthesis, respiration, absorption, translocation and utilization of mineral nutrient. The application of water and its managed uses has been an essential factor in raising productivity of agriculture and ensuring predictability in output (FAO, 2002). Sustainable water management helps to ensure better production both for direct consumption and commercial disposal.

The competition for freshwater resources between domestic demands, industry, commerce, institutions such as hospitals, and agriculture has increased as a result of increase in world population. Water demand has tripled since the 1950s (Brown, 2003). A huge increase in the number of wells and over-pumping with increasingly powerful diesel and electrical pumps is leading to falling water tables. Surface water from rivers is also tapped for freshwater and major rivers either completely dry up before reaching the sea or contain only a very small volume of water. About70% of surface and groundwater is used for agriculture, however with increasing competition between agriculture, industry and domestic demand, agriculture is beginning to receive less water (Brown, 2003).

The use of wastewater for agriculture in and around cities across the world is a current and future reality that cannot be denied. In some countries, such as Mexico and China, it has been practiced for centuries (Shuval *et al.,*1986). Since conventional treatment is very costly, most wastewater is allowed to be dumped, untreated, into water bodies or onto the land. The growing demand of water for irrigation has produced a marked increase in the reuse of treated and/or untreated wastewater worldwide. The use of industrial or municipal wastewater in agriculture is a common practice in many parts of the world (Blumenthal *et al*., 2000; Ensink*et al*., 2002; WHO, 2006; Sharma *et al*., 2007). Rough estimates indicate that at least twenty million hectares in 50 countries are irrigated with raw or partially treated wastewater (Hussain*et al.,* 2001; Scott *et al*., 2004). The major objectives of wastewater irrigation are that it provides a reliable source of water supply to farmers and has the beneficial aspects of adding valuable plant nutrients and organic matter to soil (Horswell*et al.*, 2003; Liu *et al*., 2005).

Untreated wastewater use for peri-urban agriculture is often either ignored or actively condemned by the public and by government officials. A primary exposure route for urban population in general is the consumption of raw vegetable that have been irrigated with urban wastewater (Scott *et al*., 2004). In many developing areas however, non-built up urban lands, especially those lying along the courses of urban drainage systems, are sometimes seen as locations for the production of some agricultural products that are in high demand by urban dwellers (such as vegetables). Several researchers have shown that a significant proportion of a city's food requirements in developing countries are supplied from within the urban boundaries, because within those areas, substantial amount of wastewater (mainly from homes and industries) is available in urban drains for irrigating lands along the urban drainage courses. Since the early 1990s, in particular, there has been increasing recognition amongst the scientific and development communities of the rising importance of wastewater-based food production in city areas, particularly in those parts of the world that have been characterized by economic collapse (Mbiba and Van Veenhuizen, 2001).

Demand for water by peri-urban vegetable production compounds already existingcompetition from residential and industrial users for limited supplies in an environmentwhere the marginal value product of water is high, heightening potential conflict(Abernethy, 1997). Increased construction in cities leads to reduced infiltration,increased runoff, less underground water storage and greater flooding risk. To some degree the retention of vegetable fields nearcities, whether intentional or serendipitous (e.g. empty lots awaiting construction),offset these issues and certainly should be encouraged. An excellent example is theretention in Taiwan of the intensive horticultural region of Chang Huacounty in anarea of rapid industrial development.

Besides quantity, quality of metropolitan water as affected by industrialization,urbanization, sewage/effluent disposal and agricultural practices, has importantimpacts on vegetable quality and sanitation. Grey water can be used in powerstations and for other industrial applications, treated effluent can be used in peri-urbanagriculture, and potable water for domestic purposes. Taxing the use of waterresources offers a potential solution to further regulate its allocation, as in the Netherlandswhere peri-urban farmers not only are liable to a tax on their use ofgroundwater resources but also subject to a compulsory registration system regardingthe quantities of ground water used and drain water produced. A simpler system isin place in India: farmers irrigating with sewage water in the Hubli–Dharwad twincity pay a nominal annual charge to the twin city corporation, but this is notenforced (Nunan, 2000). Only with enforcement could water treatment and distributionbe improved.

2.3 Input Use in Peri-urban Farming

2.3.1 Seed Source

Peri-urban farmers source for their seed locally or from produce. Farmers use the carryover seed stock from previous year for planting. Most peri-urban farmers obtain their seed for the next cropping season from the remnant of the field. Vegetables are rarely cultivated to produce seeds (Akoroda and Akintobi, 1983). The advantage of local seed multiplication is that cost of transportation and packaging that constitute bulk of the overall production cost is removed (Cromwell, 1994).

Non–availablity of improved seed is a major challenge to productivity of Peri-urban vegetable farming (Adeboye*et al.,* 2005). Okafor (1979) reported that 83.3% of farmers sampled in Nigeria identified lack of seed and planting materials as a major constraint to productivity. Most farmers extract their seed by crude methods which adversely affect seed quality and viability leading to seed deterioration and production of weak seedling. Also, plants are usually left in the field for too long thereby exposing seeds to disease and infection. When fruits are left on the plant for too long, some fully ripe inflorescence will shatter and shed their seeds resulting in wastage.

2.3.2 InorganicFertilizer

The use of inorganic fertilizers in vegetable production has in the past generated concern about the health effects, especially of nitrates in fresh leafy vegetables (Ngigib*et al.*, 2010). Application of nitrate fertilizers in vegetables by smallholder is common both in developing and developed countries (Santamaria, 2006). Nitrates are safe. However, its metabolite nitrite is carcinogenic hence ingestion of nitrates may have long term health effect (Sanchez-Echaniz*et al.*, 2001).

Phosphate fertilizer are considered to be the major source of heavy metals input especially cadmium in pastoral soils in Australia and New Zealand and paddy soil in Asian countries. There have been greater efforts to reduce the accumulation of Cd in soils through the use of low Cd-containing phosphorus fertilizers. This is achieved by either selective use of phosphate rocks with low Cd or treating the phosphate rocks during processing to remove Cadmium. Superphosphate fertilizer manufacturers in many countries are introducing voluntary controls on the Cd content of phosphate fertilizers. For example, the fertilizer industry in New Zealand has achieved its objective of lowering Cadmium content in phosphate fertilizers from 340mg $Cdkg^{-1}$ P in the 1990s to 280mg$Cdkg^{-1}$ P by the year 2000. A number of phosphate rocks with low Cd are available which can be used in many countries for practical and economic reasons (Bolan *et al.*, 2003).

Several chemical processes to remove Cd from phosphoric acid before it is converted to phosphate fertilizers have been examined.These include extraction of wet phosphoric acids with amine and by ion exchange resins. For example, calcinations which refer to heating of phosphate rocks usually in the presence of silica and steam are aimed at reducing Cd content through its volatization. However, calcinations may not become a likely option in the fertilizer industry because it isexpensive and calcinations decrease the reactivity of phosphate rocks, making them less suitable for direct application as a source of phosphate (Bolan *et al.*, 2003).

2.3.3 Organic Nutrient/Manure

In addition to inorganic fertilizers, different materialsare also frequently used as sources of organic nutrient e.g animal manure of which poultry waste is the most sourced for. Poultry waste is an important soil ameliorating resource for vegetable production. Types and quality of poultry waste product hardly receive consideration when the waste is being sourced. Poultry waste is usually a combination of poultry bird faeces, urine, saw dust and remnants of animal feeds, drugs and pesticides. Conveyance cost is usually high due to its weight and bulkiness. There are no specific vehicles assigned or designed for poultry waste haulage, no standard measures for poultry waste collection and packaging although the informal nature of the poultry waste business plays a major role. Storage of poultry waste is mainly by heaping and covering. Poultry waste is buried in between farm ridges and covered with leaves. This mode of treatment is adopted due to lack of skill for proper composting methods, insufficient space, time and paucity of capital. Other reasons are the burdensomeness of the long processes required for its treatment and inadequate access to other needed materials such as ash. Application is manual and it is done without protective gadgets like boots and nose mask. Reasons for non use of protective gadgets relate more on non economic factors like ease and convenience of application. With these perceived benefits associated with poultry waste utilization, the challenges and uncertainty about its quality and suitability for food production has generated research interest particularly with some reported cases of poultry bird flu in parts of the world including Nigeria. Apart, larger number of empirical studies in African cities on the use of poultry waste for food production has focused more on the fertilizing value than on the health and environmental impacts (Kiango*et al*., 2001; Nsiah-Gyabaah*et al*., 2001).

Poultry waste addition is increasingly being recognized as a major source of metal input to soils, with repeated applications having resulted in elevated concentration of metals in soil. For example, the annual metal inputs to agricultural land in England and Wales from animal manures amounted to 5247, 1821and 225mg/kg of Zn, Cu and Ni, respectively which represent 25-40% of the total inputs (Nicholson *et al.*, 1999). Similarly, Jinadasa*et al*. (1997) surveyed Cd levels in vegetables and soils of Sydney, Australia and concluded that the increase in Cd and Zn in vegetable soils were due to repeated applications of poultry manure.

Xiong*et al*. (2010) investigated the concentration of Cu in pig, cattle, chicken and sheep manure in China and showed that the mean Cu concentration in pig, cattle, chicken and sheep manure were 699.6, 31.81, 81.8and 66.85mg/kg, respectively. This can be a major input of Cu to agricultural land. Similarly, in New Zealand, land application of dairy pond effluent, based on Nitrogen loading of 150kg N ha^{-1}, is likely to add maximum of 31.5kg Cu ha^{-1} and 73.7kg Cu ha^{-1} through effluent and manure sludge application, respectively (Bolan *et al*., 2003). Martinez and Peu (2000) estimated that 183kg Cu and 266kg Zn, respectively, were added to soil through 8 years of swine manure application, most of which accumulated in the surface soil.

Metals in manure by-products are also derived from ingestion of contaminated soil by animals and also during manure collection and handling, a number of metals are added to livestock and poultry feedstuff not only as essential nutrients but also as supplements to improve health and feed efficiency. In confined intensive animal production systems, a number of feed additives are used to improve feed efficiency and to reduce out-breaks of diseases (Papaioannou*et al*., 2005). Among the many feed additives,the metal(loid)s As, Co, Cu, Fe, Mn, Se, and Znare added to prevent diseases, improve weight gains and feed conversion, and increase egg production in the case of poultry (Mondal*et al*., 2007). Similarly, regular use of growth promoters containing metals is likely to result in elevated concentrations of these metals in excreted faeces and urine, concentration in manure by-products depend primarily on their concentrations in the diet (Mondal*et al*., 2007). For example, Kunle*et al*.(1981) and Sutton *et al*. (1983) observed that Cu concentration in swine and poultry manure by-products were linearly related to Cu added in the diet. Similarly, Mohanna and Nys (1999) noticed that by reducing dietary Zn from 190mg/kg to 65mg/kg in broiler poultry feed resulted in a decrease of Zn concentration in manure by 75%. Introducing highly viscous raw materials such as triticale, rye and barley at high levels in poultry diets has been shown to reduce Zn retention, thereby contributing to increase level of Zn in manure (Mohanna and Nys,1999). Mondal*et al*. (2007) obtained a significant correlation (R^2=0.89, $p<0.05$) between Cu in swine feed and faeces Cu concentration. The concentration of Cu in feed samples ranged between 6.86mg/kg and 395.19 mg/kg and Cu concentration in pig faeces were approximately 5-times greater than in pig feed.

As in the case of animal diet, the majority of metals used in animal health remedies also eventually reach the end-use by-product. Addition of As to feed as an additive to control coccidiosis in poultry has been shown to result in seven fold increase in As level in poultry litter (Mohanna and Nys, 1999). Similarly the excessive use of Cu compounds as growth promoter in swine and poultry, and as afootbath in milking yards to treat lameness in dairy cattle can result in elevated concentration of Cu in effluents and manure products (Bolan *et al*., 2003).

Christen (2001) obtained a direct correlation between water extractable As in soils and the amount of poultry litter applied, implicating this materials as a major source of As input in soils. The organic As compounds have been used as feed additives for swine disease control and weight improvement in China. Li and Chen (2005) investigated Asconcentration in pig feeds and manure ranged from 0.15 to 37.8mg/kg and 0.42 to 119.0mg/kg, respectively. They reported that the potential soil As increase rates resulting from land application of pig manure might range between 11.8g kg^{-1} $year^{-1}$ based on the loading rates of pig manure of 2.7-57.2t ha-^{1} $year^{-1}$.

Soil ingestion has been identified as an important source of Cd ingestion by grazing sheep and cattle in New Zealand and Australia (Mondal*et al*., 2007). For example, it has been estimated that in New Zealand, sheep ingest 11-30g soil per day soil in the summer and 264-275g soil per day during the winter. The corresponding values for cattle are 220-470g soil per day in summer and 900-1600g soil per day in winter (Mondal*et al.*,2007). Based on these values and the average Cd concentration of 0.1-0.5mg/kg in pasture soils, it can be estimated that approximately 15mg and 90mg of Cd is ingested annually through soil by sheep and cattle, respectively most of which is excreted in the manure.

2.3.3 Agrochemical Products

Agricultural use of pesticides and herbicides is another source of heavy metals in arable soils from non-point source contamination. Although pesticides and herbicides containing Cd, Hg, and Pb have been prohibited in 2002, there are still other trace elements containing pesticides and herbicides in existence, especially Cu and Zn. It was estimated that a total input of 5,000 tons of Cu and 1,200 tons of Zn were applied as agrochemical products to agricultural land in China annually (Luo*et al.*, 2009). Cocoa, groundnut, mustard and rice in China had elevated concentrations of heavy metals (especially Cu and Zn) assessed when compared to other plants (cabbage, oil palm, and lady's fingers). This may be contributed by the widespread use of Cu and Zn pesticides on these crops.

2.4 Environmental Impacts of Peri-urban Farming

Over recent decades, peri-urban agriculture has made tremendous adjustment to meet the growing demand for inexpensive and safe supply of vegetables during the dry season and this growth has been accompanied by the emergence of "land-dependent" farming establishment. All setbacks along major highways are used for peri-urban farming. As a consequence, contaminated soils are unwittingly put into cultivation. Due to the fact that industries are mainly located in peri-urban areas, often in close existence with agriculture (Navano-Avino *et al.*, 2007), has caused a serious contamination of agricultural soils with heavy metals and turn them into a long term sink (Kabata-Pendias, 2011).

The extra-ordinary performance of peri-urban farming over the past three decades have been partially achieved through soaring use of inorganic and organic fertilizers as soil amendment. The intensification in the use of fertilizers resulted in expansion of cropland at the expense of forested land (deforestation), pollution in arable soil through intensive use of mineral fertilizer, herbicides, pesticides to maintain high crop yield also contributed to air pollution. Nitrous oxide produced from N fertilizer is a major air pollutant. FAO-IFA (2001) reported a 1 % N_2O-N (nitrogen in nitrous oxide). Green house gases emission got increased most importantly from deforestation.

Pollution of soil and water with heavy metals and pathogens is also a result of poor-manure management. Excessive use of agricultural input such as pesticides, inorganic fertilizer, raw organic matter may run off into water sources contaminating aquatic life. Water pollution from surface run off has been reported in literature with subsequent effects on nutrient enrichment, water quality impairment, marine life spawning, ground destruction and fish kill (Ogunfowokan *et al.*, 2005; Taiwo, 2010). Asimi (1998) also noted that effluents from farms increased water COD, total water hardness, turbidity among other water quality variables. Over exploitation of water resources during the dry season could result in draining of wetlands and reduction in biodiversity.

Local disturbance and landscape degradation are typical local negative amenities of peri-urban farming. Diversion of water ways and re-channeling for irrigation is a significant environmental issue resulting from peri-urban agriculture. Sometimes farming practices are done on flood plains, river banks, steep slopes and water side contributing to flooding and erosion. Substantial amount of waste water is used for irrigation in peri-urban farming. Talukder *et al.*(1998) reported that poor quality irrigation water reduces soil productivity, changes soil physical and chemical properties, create crop toxicity and ultimately reduces yield.

2.5 Heavy Metals Contamination in Peri-urban Farming

A valid definition for the term "heavy metals" has never been established (Duffs, 2002) nor has the term "trace metals", which is often used synonymously, ever been defined exactly (Kabata-Pendias, 2011). Several sources defined heavy metals as elements with a density greater than 5 g/cm^3 (Morris, 1992). Heavy metals are environmental contaminant of great concern because due to their biochemical properties, they accumulate in environmental media (Kabata-Pendias,2011). With respect to their toxicity, heavy metals can be divided into two groups: micronutrients like Fe, Mn, Mo, Cu, Ni and Zn and are essential in small amounts and the only toxic ones As, Cd, Hg, and Pb without any known biological function. The latter ones have higher impact on organisms, but even the essential heavy metals can become toxic if a specific concentration level is exceeded (Alloway, 1999).

Exposure to heavy metals continues to be an important issue today particularly in developing countries (Adriano, 2001; Jarup, 2003). Even in developed countries it was only towards the end of the 20th century that emissions of heavy metals declined, where for example in the UK between 1990 and 2000 emissions fell by over 50% (Jarup, 2003). Natural sources of metals can even be a problem, such as in Bangladesh where high concentration of naturallyoccurring arsenic have been found in the main source of potable water sources across more than 50% of the districts (Adriano, 2001).

Elevated heavy metal soil concentration may come from either geogenic or anthropogenic sources. While metals of geogenic origin are those which occur naturally in the parent materials, anthropogenic metals are deposited in the soil due to human activity. Typically metals arising from anthropogenic sources are more bioavailable than the naturally occurring forms and consequently pose greater risks of adverse human health effect.

Contamination of soilswithheavy metals from anthropogenic activities is widespread and represent a serious problem for scientist and government throughout the world. The process and pathways by which contamination occur are varied including combustion followed by atmospheric deposition, run-off into surface waters from chemical spills storage and transport and direct application of products containing heavy metals to soils (Jarup, 2003).The United State Environmental Protection Agency (USEPA) has 13 metals on their priority pollutants list including Ag, As, Be, Cd, Cr, Cu, Hg, Ni, Pb, Sb, Se, Ti, and Zn. Each of these metals presents a unique problem for soil scientists researching contamination problem.

Wastewater irrigation, solid waste disposal, sludge applications, vehicular exhaust and industrial activities are the major sources of soil contamination with heavy metals, and an increased metal uptake by food crops grown on such contaminated soils is often observed. In general, wastewater contains substantial amounts of beneficial nutrients but also toxic heavy metals, which are creating opportunities and problems for agricultural production, respectively (Singh *et al*., 2004; Chen *et al*., 2005). "Excessive accumulation of heavy metals in agricultural soils through waste water irrigation, may not only result in soil contamination, but also lead to elevated heavy metal uptake by crops, and thus affect food quality and safety" (Muchuweti*et al*., 2006).

Heavy metal accumulation in soils and plants is of increasing concern because of the potential human health risks. This food chain contamination is one of the important pathways for the entry of these toxic pollutants into the human body. Heavy metal accumulation in plants depends upon plant species, and the efficiency of different plants in absorbing metals is evaluated by either plant uptake or soil-to plant transfer factors of the metals (Rattan *et al.*, 2005). Uptake of metals by plants may be a good indicator of efficiency of metal absorption of different crop species grown on soils having uniform metal level under controlled conditions. Whereas transfer factor of metal from soil to plants indicate the efficiency of crop species better where crops are grown on soils having variable metal content.

Heavy metals which are persistent environmental contaminants maybe deposited on the surfaces and then absorbed into the tissues of vegetables. Plants take up heavy metals by absorbing them fromdeposits on the parts of the plants exposed to the air from polluted environments as well as from contaminated soils (Khairiah*et al*., 2004; Jassir*et al*., 2005; Kachenko and Singh, 2006; Singh and Kumar, 2006; Sharma *et al*., 2008a,b). A number of studies have shown heavy metals as important contaminants of the vegetables(Singh *et al.*, 2004; Marshall, 2004; Sinha*et al.*, 2006; Singh and Kumar, 2006; Sharma *et al*., 2006, 2007, 2008a,b). Heavy metalcontamination of vegetables may also occur due to irrigation with contaminated water (Singh *et al*., 2004; Sharma *et al*., 2006, 2007; Singh and Kumar, 2006). Emissions of heavy metals from the industries and vehicles may be deposited on the vegetable surfaces during their production, transport and marketing. Jassir*et al*. (2005)

reported elevated levels of heavy metals in vegetables sold in the markets at Riyadh city in Saudi Arabia due to atmospheric deposition. Recently, Sharma *et al*. (2008a,b) reported that atmospheric deposition cansignificantly elevate the levels of heavy metals contamination in vegetables commonly sold in the markets of Varanasi, India

2.6 Soil-plant-man Interaction for Heavy Metals

According to Kosvacs (1992), plants, most especially ruderals, have the ability to bio-accumulate metals in high quantities without visible injury. Heavy metal absorption by plants is governed by soil characteristics such as pHand organic matter content (Jones, 1991; Sinlatan and Tuba; 1992). It has been reported that individual plant species greatly differ in their uptake of heavy metals.

The speciation and levels of the metal in the soil solution, the movement of the metal from the bulk soil to the root surface, the inward movement of the metal from the root surface, and the translocation of the metal from the root to the shoot come into play in determining the amount of metals absorbed by a plant (Wild, 1988). Plants do vary in their absorptive mechanism for different ions, but ions which are absorbed into the root by the same mechanism are likely to experience competition. For example, Zn absorption is inhibited by Cu and H^+ but not by Fe and Mn while Cu absorption is inhibited by Zn, NH_4^+, Ca and K (Graham, 1981; Barber 1984). The uptake of heavy metals by plants is determined by the increasing level of soil contamination (Alloway and Davies, 1971; Gracia*et al*., 1979; Grant and Dobbs, 1997).

Foliar absorption of solute is essential at meeting food need of mankind. Lingle and Holmberg (1975) used foliar sprays of Zn to correct deficiency of Zn in plants. Also demonstrated was the uptake of Zn from foliar sprays in bean plants by Bukavoc and Wittwer (1957). Tjell *et al*. (1979) reported foliar absorption to be significant route for the entry of atmospheric pollutants such as Cd into the food chain. Lead may remain largely as a superficial deposit on the leaves whereas Zn and Cd exhibited at least partial penetration into the leaves (Little and Martins, 1972).

Foliar absorption has a role to play in heavy metals uptake. Roots of plants are responsible for absorption of water and mineral elements but absorption of elements also takes place through the leaves. Also, foliar route has been reported to be of equal importance to the soil-root pathway (Alfaeni *et al.*, 1996). The primary source of heavy metals in the aerial parts of plant is generally said to be via aerial deposition (Bilegaard and Johnson, 1984; Chamel, 1986; Marschner, 1986; Bache *et al*., 1991; Zhang *et al*., 1995). Direct uptake of heavy metals through the leaf after deposition is an important route especially for lead (Breckle and Khale, 1992). The deposited particles may be washed by rain into the soil, re-suspended or retained on leaves (Harrison and Chirgawi, 1989). The degree of retention of metal is influenced by weather conditions, nature of pollutants, plant surface characteristics and particle size (Harrison *et al*., 1989). Great variation in heavy metal concentration in plants had been reported to depend on species and metal type (Agrawal*et al.*,1988; Jones, 1991; Snatalan and Tuba, 1992).

A number of factors contribute to the foliar absorption of solutes. These include plant species, nutritional status, age of the leaf, thickness of cuticle, presence of stomata guard cells, humidity of the leaf surface and the nature of solutes (Chamel, 1986; Marschner, 1986). Also reported was that particles deposition on leaf surfaces is affected by some factors, including particle size and mass, wind velocity, leaf orientation, sizes, moisture level and surface characteristics (Bache *et al*., 1991).

Soil-to-plant transfer is one of the key components of human exposure to metals through the food chain. Lacatusu*et al*. (1996) studied soil-plant-man relationship in heavy metals polluted areas in Romania and detected significant levels of Cd and Pb from the geogenic abundance viewpoint. Although the polluted soils were neutral to slightly alkaline and well supplied with organic matter, the soluble forms of heavy metals in EDTA-CH_3COONH_4, pH =7.0 represented on average 37% Cd, 17% Cu, 28% Pb and 14% Zn, respectively of their global concentration, exceeding the maximum allowable limit (MAL), for soluble forms, by on average up to 14.8 (Pb), 4.2 (Cd), 2.1 (Zn) times. The relationship between their contents in plants and in soil (soluble forms) showed significant correlations for Cd, Cu, Pb and Zn. As a result, the contents of these elements in vegetables often exceed those allowable for normal human and animal consumption.

In this case, if an adult consumed 2kg potatoes, 2kg tomatoes and 1kg carrots in a week, his or her food would exceed by 12% the MAL for Cd (0.525mg). The daily maximum allowable rate of ingested Pb (0.430mg) could be reached by consuming 880g of vegetables (equal parts of potatoes, tomatoes, carrots and cucumbers). Acidity of soils enhances the transfer of large amounts of heavy metals in soluble forms, exceeding MAL on average up to 23.4 (Pb), 2.1 (Cd), 2.8 (Cu) and 2.7 (Zn) times. As a result, the average Pb content in carrots was 10 times higher than the MAL and the Pb accumulation in the lettuce, Parsely and garden orach, significantlyabove the critical contents. At the same time, the Cd content in the analysed vegetable exceeded by 5 times the MAL, while the Cu and Zn contents were close to critical levels (Lacatusu*et al.*,1996). Ingestion of vegetables containing high concentration of heavy metals is one of the main ways in which these elements enter the human body.

Estimates from various countries showed the dietary intake for Pb in adults is between 54mg per day (Arora*et al.*, 2008) and 412mg per day (Lacatusu*et al*. 1996) and that of Cd is between 10 and 30mg per day (Arora*et al.*, 2008). For Zn and Cu, the estimated daily intake is from 1 to 3 mg, and 10 to 20mg respectively (Arora*et al.*, 2008). Lacatusa*et al*.(1996) found that their estimation for Pb and Zn in adults were above those reported from other countries whereas the estimation for Cd was within the range. The levels of Cu were observed to be below the estimation.

Bahemuka and Mubofu (1999) suggested that a large daily intake of these vegetables is likely to cause a detrimental health hazards to the consumers. Since the dietary intake of food may constitute a major source of long-term low-level body accumulation of heavy metals, the detrimental impact becomes apparent only after several years of exposure. Regular monitoring of these metals from effluents, sewage, manure, in vegetable and in other food materials is essential for preventing excessive build-up of the metals in the food chain (Bahemuka and Mubofu, 1999).

2.7 Peri-urban Vegetable and Human Health

Vegetables cultivated in wastewater-irrigated soils take up heavy metals in large enough quantities to cause potential health risks to the consumers. In order to assess the health risks, it is necessary to identify the potential of a source to introduce risk agents into the environment, estimate the amount of risk agents that come into contact with the human-environment boundaries, and quantify the health consequence of the exposure (Ma *et al.*, 2006). Heavy metal contamination of vegetables cannot be underestimated as these foodstuffs are important components of human diet. Vegetables are rich sources of vitamins, minerals, and fibres, and also have beneficial antioxidative effects.In view of their generally high vitamin and micro-nutrient content, vegetables arecommonly valued as an essential component of the human diet (Ali and Tsou, 1997)and peri-urban vegetable production contributes substantially to the sum total consumed within cities (e.g. 75% of annual consumption in Ho Chin Min City (Jansen *et al.*, 1996)and 80% in Hanoi (Tran, 2000).Although largely unquantified, peri-urban vegetable production contributes to theaesthetic properties of the urban–rural divide (FAO, 1999). Wang (1997) noted the shift in population away from city centres to peri-urban zones, presumably foran improved lifestyle. Smardon (1988) discussed the impact of green vegetation ongeneral human health and wellbeing.

Intake of heavy metal-contaminated vegetables may pose a risk to the human health. Heavy metal contamination of food items is one of the most important aspects of food quality assurance (Marshall, 2004; Wang *et al.*, 2005; Radwan and Salama, 2006; Khan *et al.*,2008). International and national regulations on food quality have lowered the maximum permissible levels of toxic metals in food items due to an increased awareness of the risk these metals pose to food chain contamination (Radwan and Salama, 2006).

Peri-urban vegetables may exert a negative impact on the healthof the urban populace via induced infections/toxicities attributed to the consumptionof contaminated vegetables, even though the risks of human infection do not seemto be more serious than through consumption of vegetables produced in rural areas(Senouci*et al.*, 1993;Albrecht *et al.*, 1995). Although health risks from the use of organic urban wastes in peri-urban agriculture are often considered minimal(Furedy, 1996), human toxicity due to high concentration of heavy metals sometimescan occur in produce from peri-urban sources, e.g. in Hanoi (Tran, 2000). In addition,where peri-urban farmers in Hanoi use fresh human manure in peri-urban vegetablefarming, virtually all children suffer from helminthiasis (Dang, 2000). In Burkina Faso, Ouedraogo *et al*. (2017) also reported that prevalence of gastroenteritis is usually higher in dry season among children compared to wet season. Finally, as inHo CinMinhCity (Jansen *et al.*, 1996) and Bangkok (Waibel and Schmidt, 2000), the widespreadoveruse of both inorganic fertilizers and pesticides by peri-urban vegetablegrowers is a potential danger to environmental health.

Prolonged consumption of unsafe concentrations of heavy metals through foodstuffs may lead to the chronic accumulation of heavy metals in the kidney and liver of humans causing disruption of numerous biochemical processes, leading to cardiovascular, nervous, kidney and bone diseases (WHO, 1992; Jarup, 2003). When ingested in trace quantities, some heavy metals such as Cu, Zn, Mn, Co and Mo act as micronutrients for the growth of animals and human beingswhereas others such as Cd, As, and Cr act as carcinogens (Feig*et al.*, 1994; Trichopoulos, 1997), and Hg and Pb are associated with the development of abnormalities in children (Gibbes and Chen, 1989; Pitot and Dragan, 1996).Hartwig (1998) and Saplakog¢lu and Iscan (1997)have reported that long-term intake of Cd caused renal, prostate and ovarian cancers in human.

Fortunately however, the degree of microbial contamination is amenable to bothproduction and post-harvest management. Judicious management and use of sewageeffluent can reduce exposure to coliform bacteria, e.g. by covering the soil withplastic sheeting (Sadovski*et al*., 1978). Rinsing of contaminated vegetables causesmeasurable differences in bacterial counts and a chlorine wash solution reduced coliformpopulation on broccoli by one log unit (Rosas *et al*., 1984). Objective inoculationwith selected lactic acid bacteria (*Lactobacillus casei*strains) is effective inreducing or eliminating populations of coliforms and enterococci after the third dayof refrigerated storage (Vescovo*et al*., 1995).

From a policy point of view, WHO guidelines exist for the safe use of wastewaterand excreta in agriculture (Mara and Cairncross, 1989) and for acceptable concentrationsof various organic and inorganic compounds in soils treated with reclaimedwater and sewage sludge (e.g. Chang *et al*., 1995). Given the current and likelyincrease in use of sewage and effluent for peri-urban vegetable production, attentionto the possible impacts of heavy metals on the safety of vegetable consumption isappropriate even though the evidence regarding their potential harm is mixed. Nosignificant difference in heavy metal content was observed in a comparison betweenvegetable plants irrigated with well water or treated municipal waste water (Burau*et al.*, 1987), and preliminary evidence from West Africa (Bamako in Mali and

Ougadougouin Burkina Faso) suggests that heavy metals, even though present in organicwaste material, are not currently an issue of immediate concern. On the other hand, one study has found positive correlationsbetween plant lead (Pb) concentrations in lettuce and the lead concentration in thesludge to lower the concentration of Pb (Sterrett*et al*., 1996).The concern with lead appears to be confined to production in urban areas: leadwas found in high concentrations in urban soils at twice the values of rural or forestsoils of Hong Kong, and studies of urban soils in Baltimore (USA) also showedhigh average lead concentrations (Sterrett*et al*., 1996), attributable to automotive Pbemissions, aerosol emissions and Pb-based paints. The major current concern withPb is the surface deposition of Pb-enriched dust on vegetables that will then beingested, as is so in the highly urbanised Hong Kong area (Chan *et al*., 1989). Asmight be expected, distancing vegetable production from streets minimizes atmosphericdeposition of Pb particles (Smit*et al*., 1996). Approximately 50% of surfacedepositedPb is removed by surface washing.

Finally, there is the issue of nitrate content in the edible part of vegetables. Vegetables(particularly the leafy types) that are harvested during their major growthstage are still actively accumulating nitrogen and tend to have high nitrate concentrations.However, the overall effect on nitrate concentration is similar in vegetablesharvested from peri-urban and rural sources (Cerutti*et al*., 1996; Yin *et al*., 1993),and this, together with the reported levels of heavy metals in peri-urban-producedvegetables (with exceptions for lead in urban situations) should give cause forserious concern amongst consumers of peri-urban vegetables (FAO, 1999b)

CHAPTER THREE

MATERIALS AND METHODS

3.1 Location of the Study Area

The study areasare geographically located in Osun State, Southwestern part of Nigeria.The State is situated in the tropical rain forest zone. It covers an area of approximately 14,875 sq km and lies between latitude 7° 30′ N and longitude 4° 30′ E. Though a landlocked state, it is blessed with presence of many rivers and streams which serve the water needs of the state.Osun has a fairly large population. According to the 2006 National Population Census, the population of the state is put at 3,423,535 inhabitants (NPC, 2006). The mean annual rainfall is 1,330mm, though there are great deviations from this mean from year to year.The area is characterized with two prominent seasons which are the rainy and dry seasons. The rainy season lasts from mid-March to late October and rainfall is bimodal with peak periods in July and September. The dry seasonlasts from November toMarch. Annual temperature ranges from 27^{0}C to 34^{0}C with the highest range being experienced in the dry season. The study area constitutes a part of the Basement complex of Southwestern Nigeria and it is characteristically layered by hard igneous and metamorphic rocks (Symth and Mongomery, 1962).

Being an agrarian state, agriculture is largely practiced both at commercial and subsistence scales and this attracts people from outside the State. Major crops grown are cassava, maize, beans, yam, fruits and vegetables. Cash crops such as cotton, cacaoand oil palm serve the local cottage industries such as cotton weaving, cotton seed milling, cocoa and palm oil processing.

The map of the study area is presented in Fig.3.1. Many of the people in the State are involved in peri-urban farming. For the purpose of convenience and greater coverage,

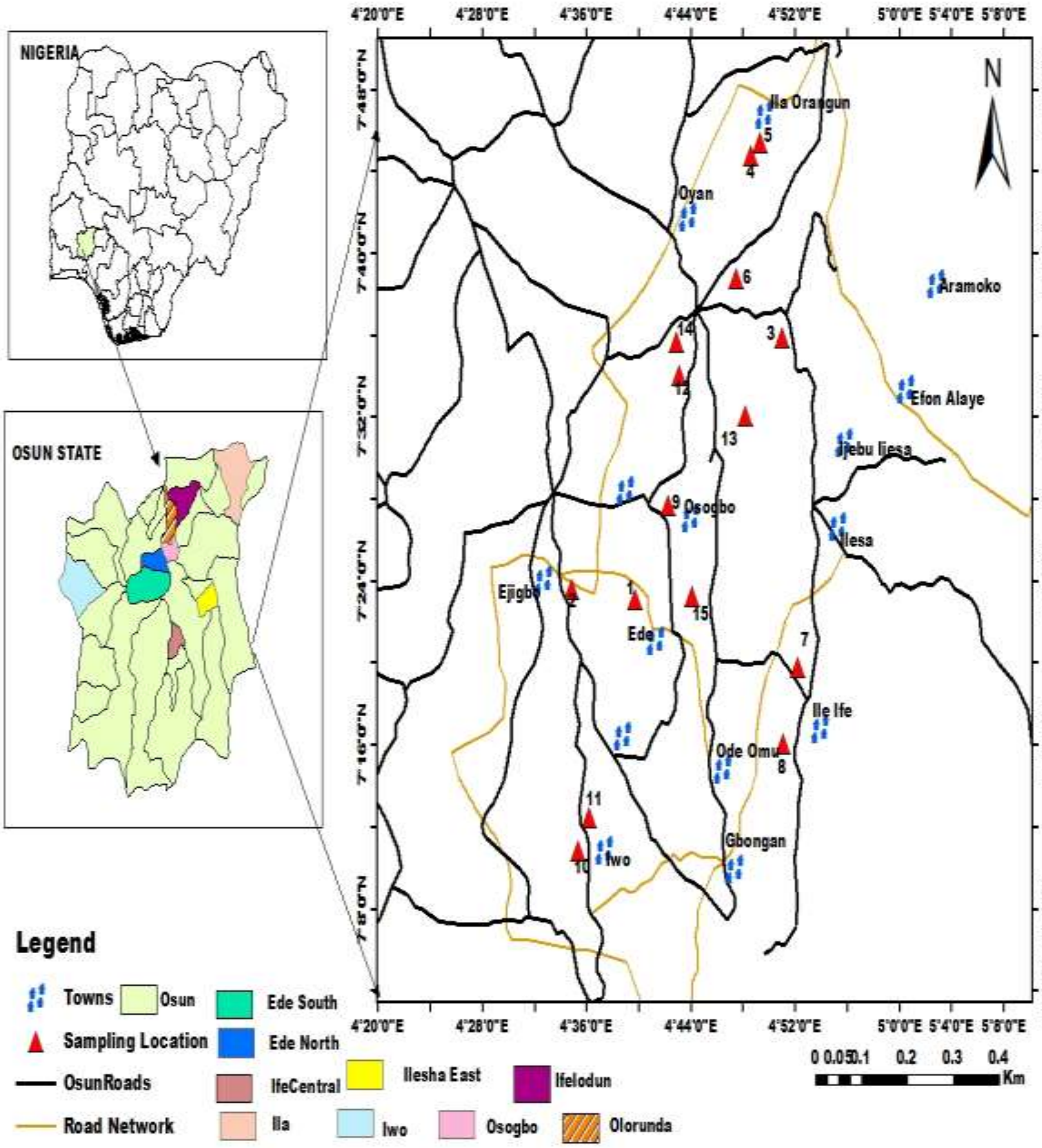

Fig 3.1: Map of Osun State Showing the Sampling Locations

sampling was carried out in seven citiesnamely; Ede, Ilesa, Ile-Ife, Ila-Orangun, Ikirun, Iwo and Osogbo. These locations were chosen because they represent the typical peri-urban dry season vegetable production system in Osun State. Osun State was specifically selected for this study because it is one of the most urbanized states in Nigeria.

3.2 Sampling Techniques

Sampling was carried out in each of the cities from Januaryto April. Soil and vegetable samples were collected during the dry season from at least two farm locations per town. Soil and edible vegetable samples from selected peri-urban farms were collected twice, during the first and second planting cycles. A total of 15 farmers were interviewed in all the locations.The study was undertaken by face-to-face interview and personal questionnaire/ assessment of the farms. Some of the questions addressed by the questionnaire includegeneral description of farming practices, sources of input, management and productivity.

3.3 Soil Sampling, Collection and Characterization

Soil samples were collected from each peri-urban farm. At each farm, soil samples were randomly collected from the upper horizon (0 -10cm) using a soil auger and bulked together to form a composite sample.Each sample was immediately placed in a labelled black polythene bag, tightly sealed and sent to the laboratory. In the laboratory, soils were air-dried, crushed and sieved through a <2 mmmesh, and then sealed in Kraft paper envelopes until analysis. Sub-samples were used to determine the desiredchemical properties. The soil pH was determined by the method of Blakemore *et al.*(1987).Percentage nitrogen was determined using Kjeldahl digestion procedure (Nelson and Sommer, 1982). Organic carbon was also determined using the chromic acid determination method (Walkley and Black, 1934).

3.4 Plant Sampling, Collection and Preparation

Whole plant samples were collected by uprooting them from the same site where soils were collected using soil auger. Two vegetable species *Amaranthushybridus*(Amaranth) and *Corchorus olitorious*(Jute mallow)were selected for health risk assessment because they are the most widely cultivated and consumed leafy vegetables in Southwestern part ofNigeria.Vegetables sampled were between 2-3 months at harvest. After harvesting, plant samples were separated into shoot and root. The shoots were packed into brown envelope and labelled accordingly for laboratory preparation while the roots were discarded. In the laboratory, vegetableshoots wereproperly washed with deionized water to remove all visible soil particles, weighed and then oven dried at 80^{o}C to constant weight. The oven dried samples were pulverized into fine powder using a stainless steel blender and passed through a 2 mm sieve. Theresulting fine powder was stored appropriately, kept at room temperature before analysis and later digested and analyzed fornitrate, As, Cd, Cu, Pb and Znconcentrations.

3.5 Control/Reference Samples

A control was set up in the greenhouse of the Faculty of Agriculture, Obafemi Awolowo University, Ile-Ife which served as reference soil and vegetable samples. Soil samples and vegetable seeds sowedwere provided respectively by the Departments of Soil Science and Land Resource Management and Crop Production and Protection in the Faculty of Agriculture. Vegetable seeds were sown in soil spread out in perforated bowls irrigated with unpolluted water and without the application of fertilizers, manures, herbicides and pesticides.Collections of samples were made twice from January to April at about the same time sampling was being carried out in peri-urban farms.

3.6 Chemical Parameters of Soil

3.6.1 pH Determination

The soil pH was determined using a suspension of 10 g of soil in 50ml of distilled water. The solution was allowed to stand for 30 min and stirred with a glass rod and the reading taken using Orion Research analog pH meter/Model 301.(Blakemore *et al.*, 1987).

3.6.2 Organic carbon and Organic matter Determination

Onegramme of soil sample was weighed into 500 ml Erlenmeyer flask. 10ml of 1.0 N potassium dichromate was added to it and swirled to mix, 20ml of conc H_2SO_4 was also added and mixed gently for 30 min. The mixture was diluted to 200ml with distillled water. Then, 10ml of 85% orthophosporic acid (H_3PO_4), 0.2g of NaF and 3-4 drops of ferroin indicator was added and the content titrated with 0.1N of ammonium ferrous sulphate (FAS) until the solution turned to wine-red,indicating the endpoint.

Milliequivalent of readily oxidizable material per gramme of soil (meq.OX./g)

Where: X= volume of FAS used in titration of reagent blank

Y= volume of FAS used in titration of sample

W= weight of the soil used

%OC =Meq. Ox./g. × 12/4000 × 1/0.77 × 100

= meq. Ox./g. × 0.39

Where: 12/4000= milliquivalent weight of carbon

1/0.77= factor for converting the carbon that actually oxidized to total carbon

100= factor to change from decimal fraction to percentage(%)

$\%OM = \%OC \times 1/0.58$

$\%OC \times 1.724$

Where 1.724is the factor for converting organic carbon to organic matter.

3.7: Percentage Nitrogen Determination in Soil and Vegetable Samples

One gramme of soil and vegetable samples were weighed into separate Kjeldahl digestion flasks. A little scoop of digestion catalyst was added after which 20 ml of concentrated H_2SO_4 was also added to the mixture after which the flasks were transferred to Kjeldahl digestion system (Tecator digestion system 1007 digester) and heated for 2hrs. The resulting mixture was allowed to cool and later made up to 100 ml with distilled water. Twenty millilitres of 2% boric acid (plus indicator) was pipetted into 100 ml Erlenmeyer flasks. The 100ml flaskswere placed under the receiving tube of the distillation unit after which 10 ml aliquots of the samples were pippeted into the distillation unit and 10 ml of 40% NaOH added. The distillation was allowed to continue until the content of 100ml Erlenmeyer flasks was about 75ml. The distillates were later titrated with standard HCl (0.01N) until the blue colour disappeared.

Calculation:

$$\%N = \frac{\text{Titre value} \times \text{concentration of acid} \times 0.014 \times \text{dilution factor} \times 100}{\text{Weight of sample taken}}$$

$\%\ \text{Nitrate} = \%N \times 4.423$ (factor for converting from % N to % Nitrate)

% nitrate was multiplied by 10,000 which is the ratio between 100 and 1000000 to convert to mg/kg.

3.8 Digestion of Samples

One grammeof both soil and vegetable samples were placed into 100ml beaker separately to which 15ml of trio-acid mixture (70% HNO_3, 65% $HClO_4$ and 70% H_2SO_4) was added in ratio 5:1:1. The mixture was digested at 80^oC until the solution became clear. The resulting solution was filtered and diluted to 50ml and later analysed for metals concentration (Ogunfowokan *et al*.,2013).

3.9 Atomic Absorption Spectrophotometric Determination of Heavy Metals

The digested soil and vegetable samples were analysed for their heavy metals (As, Cd, Cu, Pb and Zn) content using Atomic Absorption Spectrophotometer PG 990 model available at the Central Science Laboratory, O.A.U., Ile-Ife. All concentrations were reported in mg/kg.

3.10 Assessment of the Impact of Peri-urban Farming Activites on Soil Environment

3.10.1 Pollution Load Index (PLI)

Each peri-urban farm was evaluated for the extent of heavy metal pollution. The degree of soil pollution for each metal was measured using the pollutionload index (PLI) technique depending on soil metal concentrations. Thefollowing modified equation was used to assess the PLI level in soils.

$$PLI = \frac{C_{soil}\ (Samples)}{C_{reference}(References)}$$ (Liu *et al.*, 2005)

WhereC_{soil} (Samples) and $C_{reference}$(Reference)represent heavy metal concentrations in the soil samples and reference soil, respectively. A value of PLI < 1 denotes perfection and PLI > 1would indicate deterioration of site quality (Liu *et al.*, 2005).

3.11 Health Risk Assessments of Metals

3.11.1 Transfer Factor (TF)

Metals concentration in the extracts of soils and vegetables were calculated onthe basis of dry weight. The plant concentration factor (PCF) was calculated asfollows:

$$PCF = \frac{C_{plant}}{C_{soil}}$$ (Ciu *et al.*, 2005)

Where$C_{plant}$and C_{soil}represent heavy metal concentration in extracts ofvegetables and soils on dry weight basis, respectively.

3.11.2 Daily Intake of Metals (DIM)

The daily intake (DIM) of heavy metals (As, Cd, Cu, Pb, Zn) depended on the metal concentration in vegetables and the amount of consumption of the respective vegetables. The DIM of metals was determined by the following equation.

Daily intake of metals (DIM) = DVC × VMC

DVC = Daily vegetable consumption; VMC = Mean vegetable metal concentration (mg/kg)

Where daily vegetable consumption was taken as 98g of vegetables per person per day as set by the FAO/WHO (1999), for heavy metals intake based on body weight for an average adult (60 kg body weight).

3.11.3 Health Risk Index (HRI)

The health risk index (HRI) for the consumption of contaminated vegetables was assessed based on the food chain and the reference oral dose (RfD) for each metal. The HRI <1 means the exposed population isassumed to be safe.

$$HRI = \frac{DIM}{RfD}$$

Where DIM is the daily intake of metals and RfD is the reference oral dose for each metal. Reference oral dose are 0.003, 0.001, 0.04,0.004 and 0.3 mg/kg/dayfor As, Cd, Cu, Pb and Zn respectively (FAO/WHO, 2013).

3.11.4 Hazard Index (HI)

Estimation of potential health risk arising from consumption of more than one heavy metals in vegetables, the hazard index (HI) was developed by USEPA (2002) and was calculated as the total sum of the potential health risk index (HRI) of all the metals examined.

$$HI = \sum HRI_{Cd} + HRI_{Cu} + HRI_{Pb} + HRI_{Zn}$$

The magnitude of hazard index is assumed to be proportional to the extent of adverse effects or toxicity of the vegetables consumed.

3.12 Data Analysis

Descriptive statistics such as mean, standard deviation and range were used to summarize data collected from sampling sites. Statistical analysis for the cross sectional survey was carried out using Predictive Analytical software for Windows (SAS version 9.2).Analysis of variance ($p < 0.05$), cluster analysisand Pearson correlation coefficient wereused to test for association between the different variables.

CHAPTER FOUR

RESULTS

4.1: Farming and Production Practices Peculiar to Each Peri-urban Farm Studied

A total of fifteen peri-urban farmers were purposively sampled using a structured questionnaire. With regard to farm practices, planting were either on raised beds or ridges, 93%of the farmers carried out weeding by hand pulling while 7%of the farmers applied herbicide.Sixty percent of the farmers enhanced soil fertility by applying inorganic fertilizer, 13% of the farmers applied both poultry manure and inorganic fertilizers while 27% of the farmers depended on natural fertility.Sixty seven percent of the farmers irrigated with nearby streams, 7% with shallow well, 13% with river tributaries and 13% with waste water. Conveyance is by bucket/basin, drainage channels and motorized pumps. Table 4.1 shows the location, farming and production practices peculiar to each peri-urban farm studied.

4.2: Chemical Parameters of Peri-urban Farm Soils and Reference Soil

Table 4.2 shows the chemical characteristics of peri-urban farm soils and reference soil. In this study, soil pH ranged from 5.24-7.87 indicating a moderately acidic to slightly alkaline pH. Total organic carbon in the peri-urban farm soils under investigation ranged from 0.68-6.32%, indicating a low to high amount of organic carbon based on the classification of Enwezor *et al.* (1998). Organic matter in soil samples ranged from low to high with values which varied between 1.18-10.87%. The %N content of peri-urban farm soils ranged from 0.06-0.54%. The values obtained for OC, OM, %N in peri-urban farm soils were higher than that of the reference soil.

Table 4.1: Location of Peri-urban farms, Farming and Production Practices Peculiar to Peri-urban Farms Studie

Table 4.2: Chemical Parameters of Peri-urban Farm Soils and Reference Soil

Farms	pH	% OC	% OM	% N
1	5.77	1.99	3.43	0.17

2	7.09	1.21	2.08	0.10
3	5.24	4.49	7.73	0.39
4	7.24	1.05	1.80	0.09
5	5.75	2.01	3.46	0.30
6	7.23	1.15	1.97	0.10
7	7.71	0.74	1.28	0.06
8	7.27	6.32	10.87	0.54
9	7.03	1.03	1.79	0.09
10	7.82	1.68	2.88	0.14
11	7.29	3.46	5.80	0.29
12	6.52	1.25	2.15	0.11
13	7.86	0.70	1.21	0.06
14	7.87	0.68	1.18	0.06
15	7.51	1.53	2.66	0.13
Ref. soil	7.79	0.41	0.72	0.04

OC= Organic carbon OM = Organic matter % N = percentage nitrogen
Ref. soil = reference Soil
Farm 1= Owode-Ede, by the road side
Farm 2 = outskirt of Ede
Farm 3= Ilo-Ajegunle
Farm 4= Ila-Orangun, near an abandoned waste depot
Farm 5= Ila-Orangun
Farm 6 = Ido-Ijesa, near fish ponds
Farm 7 = outskirt of Ile-Ife
Farm 8= by the road side, along Ede-road, Ile-Ife
Farm 9 = along Osogbo/Ilie road
Farm 10= Outskirt of Iwo town, near a waste depot
Farm 11= between Telemu and Iwo
Farm 12= along Osogbo/Ikirun road
Farm 13= outskirt of Osogbo town
Farm 14= along Ikirun/Inisha road
Farm 15= outskirt of Osogbo town

4.3: Nitrate Concentration in Peri-urban farm Soils, Vegetables and Reference Samples

Table 4.3 shows the concentration levels of nitrate ion in soils and vegetables collected from peri-urban farms and reference samples. Nitrate levels varied between 20.45 - 240.52 mg/kg and 214.15-1,204.50 mg/kg in soil and vegetable samples from peri-urban farms respectively. Vegetables from peri-urban farms were within the permissible limit(2500-3000) mg/kg for nitrate ion in leafy vegetables by WHO/EC (1993).

4.4: Heavy Metals Concentration in Peri-urban Farm soils, Vegetables and Reference Samples

Mean heavy metals (Cd, Cu, Pb and Zn) concentration in studied peri-urban farm soils, vegetables and reference samples are shown in Tables 4.3-4.5. Concentration of heavy metals in the soils of peri-urban farms ranged between 0.18-0.63, 2.40-56.17, 0.70-36.75 and 30-300 mg/kg for Cd, Cu, Pb and Zn respectively. Concentration of heavy metals in the soils of farm 1, 7, 9, 11 varied in the order Zn > Pb > Cu > Cd while heavy metals concentration in Amaranthus and Corchorus obtained from these farms followed the order Zn >Cu >Pb > Cd. Mean concentration of heavy metals in the soils of farms 2, 3, 4, 5, 10, 12, 13, 14, 15 and reference soil varied in the order Zn > Cu >Pb > Cd. Amaranthus and Corchorus collected from these farms showed similar trend. Reference Amaranthus and Corchorus also showed similar trend. Mean concentration of heavy metals in the soil of farm 6 varied in the order Cu>Zn>Pb>Cd. A trend of Zn >Cu >Pb >Cd was observed in Amaranthus and Corchorus from this farm. Heavy metals concentration in the soil and Corchorus from farm 8 varied in the order Zn>Cu>Pb>Cd while in Amaranthus, heavy metal concentration was in the order Zn>Pb>Cu>Cd.

Table 4.3: Mean Nitrate (NO_3^-) Concentration (mg/kg) in Peri-urban Farm Soils, Vegetables and Reference Samples

Farms	Soil (mean ±SD)	Amaranthus (mean ±SD)	Corchorus (mean ±SD)
1	75.57 ± 0.03	1,145.02 ± 1.98	684.00 ± 3.90

2	45.49 ± 0.50	839.50 ± 2.50	1,053.72 ±2.70
3	170.36±0.37	715.40 ± 2.40	502.50 ± 5.00
4	40.02 ±0.23	589.00 ± 0.00	544.45 ± 9.50
5	132.28±1.29	589.60 ± 6.00	1,002.50 ±2.50
6	43.15 ± 0.15	1,174.00 ± 4.00	899.50 ±5.00
7	28.40 ± 0.10	1,055.75 ± 7.50	647.50 ± 5.80
8	240.52 ±0.52	523.75 ± 6.70	214.15 ± 1.65
9	20.45 ± 0.55	864.00 ± 4.00	538.75 ± 1.25
10	63.61 ± 0.08	942.50 ± 5.20	844.75 ± 7.50
11	128.13 ±0.14	862.75 ± 5.65	774.35 ± 3.50
12	47.56 ± 0.24	1,103.12 ±1.25	1,204.50 ±4.50
13	26.27 ± 0.27	1,025.00 ±2.01	527.75 ± 2.50
14	59.51 ±0.02	747.37 ± 3.70	497.12 ±1.25
15	32.84 ± 0.66	745.02 ± 4.70	761.54 ±3.61
Ref. Sap.	15.67 ± 0.23	410.00 ± 1.00	232.00 ± 9.50

SD = Standard deviation
Ref. Sap = reference soil and vegetable samples
Farm 1= Owode-Ede, by the road side
Farm 2 = outskirt of Ede
Farm 3= Ilo-Ajegunle
Farm 4= Ila-Orangun, near an abandoned waste depot
Farm 5= Ila-Orangun
Farm 6 = Ido-Ijesa, near fish ponds
Farm 7 = outskirt of Ile-Ife
Farm 8= by the road side, along Ede-road, Ile-Ife
Farm 9 = along Osogbo/Ilie road
Farm 10= Outskirt of Iwo town, near a waste depot
Farm 11= between Telemu and Iwo
Farm 12= along Osogbo/Ikirun road
Farm 13= outskirt of Osogbo town
Farm 14= along Ikirun/Inisha road
Farm 15= outskirt of Osogbo town

Table 4.4: Mean Heavy Metals Concentration (mg/kg) in Peri-urban Farm Soils and Reference Soil

Farms	As (mean±SD)	Cd (mean±SD)	Cu (mean±SD)	Pb (mean±SD)	Zn (mean ±SD)
1	BDL	0.18 ± 0.05	26.82 ± 0.05	36.75 ± 0.30	123.00 ± 5.25
2	BDL	0.35 ± 0.08	17.20 ± 0.10	10.57 ± 0.73	196.00 ± 4.50

3	BDL	0.20 ± 0.50	21.73 ± 0.18	4.50 ± 0.30	30.50± 1.50
4	BDL	0.23 ± 0.10	23.10 ± 0.10	11.78 ± 0.25	97.75 ± 1.00
5	BDL	0.33 ± 0.15	5.35 ± 0.13	13.45 ± 0.05	46.00 ± 1.50
6	BDL	0.28 ± 0.08	56.17 ± 0.50	5.52 ± 0.20	30.00 ± 2.00
7	BDL	0.38 ± 0.03	13.90 ± 0.08	15.00 ± 0.35	108.75 ± 3.75
8	BDL	0.23 ± 0.03	7.38 ± 0.13	5.10 ± 0.18	49.10 ±5.25
9	BDL	0.28 ± 0.05	4.25 ± 0.05	10.78 ± 0.08	60.50 ± 0.32
10	BDL	0.63 ± 0.05	42.45 ± 0.25	33.83 ± 0.20	300.75 ± 2.75
11	BDL	0.45 ± 0.05	25.58 ± 0.05	36.73 ± 0.30	256.00 ± 8.75
12	BDL	0.20 ± 0.10	2.40 ± 0.05	0.70 ± 0.30	68.75 ± 3.75
13	BDL	0.45 ± 0.13	26.03 ± 0.08	16.28 ± 0.48	253.00±17.50
14	BDL	0.22 ± 0.01	4.68 ± 0.02	5.30 ± 0.20	102.00 ± 0.01
15	BDL	0.43 ± 0.01	38.12 ± 0.01	5.46 ± 0.01	50.00 ± 0.02
Ref. soil	BDL	0.12 ± 0.01	4.95 ± 0.08	4.58 ± 0.75	69.75 ± 1.00
Limit	-	3.0^a	140^a	300^a	300^a
Limit	-	3.0^b	140^b	300^b	300^b

a = FAO/WHO (2002) permissible limitb = EU (2006) permissible limit   Ref. soil = reference soil
SD = standard deviation   BDL = below detection limit
Farm 1= Owode-Ede, by the road side   Farm 2 = outskirt of Ede
Farm 3= Ilo-Ajegunle   Farm 4= Ila-Orangun, near an abandoned waste depot
Farm 5= Ila-Orangun   Farm 6 = Ido-Ijesa, near fish ponds
Farm 7 = outskirt of Ile-Ife   Farm 8= by the road side, along Ede-road, Ile-Ife
Farm 9= along Osogbo/Ilie road   Farm 10= Outskirt of Iwo town, near a waste depot
Farm 11= between Telemu and Iwo   Farm 12= along Osogbo/Ikirun road
Farm 13= outskirt of Osogbo town   Farm 14= along Ikirun/Inisha road
Farm 15= outskirt of Osogbo town

Table 4.5: Mean Heavy Metals Concentration (mg/kg) in Amaranthus Produced from Different Peri-urban Farms and Reference Amaranthus

Farms	As (mean±SD)	Cd (mean±SD)	Cu (mean±SD)	Pb (mean±SD)	Zn (mean ±SD)
1	BDL	0.80 ± 0.08	5.03 ± 0.10	2.65 ± 0.23	95.00 ± 20.00
2	BDL	0.83 ± 0.10	5.98 ± 0.13	4.95 ± 0.23	158.80 ± 3.25
3	BDL	0.73 ± 0.05	6.60 ± 0.01	3.10 ± 0.10	87.50± 1.25

4	BDL	0.55 ± 0.08	9.38 ± 0.15	8.28 ± 0.35	108.00 ± 3.50
5	BDL	0.30 ± 0.05	0.85 ± 0.10	0.80 ± 0.18	41.75± 1.75
6	BDL	0.58 ± 0.05	3.30 ± 0.08	2.10 ±0.20	123.00 ± 2.00
7	BDL	0.28 ± 0.08	1.30 ± 0.08	1.18 ± 0.01	61.75 ±0.18
8	BDL	0.70 ± 0.01	9.60 ± 0.13	11.55±0.10	108.75 ± 1.75
9	BDL	0.55 ± 0.15	3.65 ± 0.05	2.63 ± 0.38	107.50± 3.50
10	BDL	0.21 ± 0.01	5.20 ± 0.14	4.81 ± 0.01	105.00 ± 0.02
11	BDL	0.50 ± 0.13	4.58 ± 0.08	4.45± 0.40	101.50 ±0.25
12	BDL	0.55 ± 0.25	4.20 ± 0.08	3.00 ± 0.15	76.25 ± 3.25
13	BDL	0.35 ± 0.10	4.78 ± 0.05	1.08 ± 0.10	77.25 ± 2.25
14	BDL	0.21 ± 0.01	3.52 ± 0.01	2.44± 0.01	84.98 ± 0.01
15	BDL	0.23 ± 0.01	5.45 ± 0.02	3.42 ± 0.02	32.00 ±0.01
Ref. amar	BDL	0.15 ± 0.01	3.00 ± 0.08	2.03 ± 0.01	43.00 ± 1.75
Limit	0.43[a]	0.20[a]	40.00[a]	0.30[a]	50.00[a]
Limit	-	0.20[b]	20.00[b]	0.43[b]	50.00[b]

a= FAO/WHO(2002) permissible limit b=EU (2006) permissible limit Ref. amar = reference Amaranthus
SD = standard deviation BDL = below detection limit
Farm 1= Owode-Ede, by the road side Farm 2 = outskirt of Ede
Farm 3= Ilo-Ajegunle Farm 4= Ila-Orangun, near an abandoned waste depot
Farm 5= Ila-Orangun Farm 6 = Ido-Ijesa, near fish ponds
Farm 7 = outskirt of Ile-Ife Farm 8= by the road side, along Ede-road, Ile-Ife
Farm 9 = along Osogbo/Ilie road Farm 10= Outskirt of Iwo town, near a waste depot
Farm 11= between Telemu and Iwo Farm 12= along Osogbo/Ikirun road
Farm 13= outskirt of Osogbo town Farm 14= along Ikirun/Inisha road
Farm 15= outskirt of Osogbo town

Table 4.6: Mean Heavy Metals Concentration (mg/kg) in Corchorus produced fromdifferent Peri-urban Farms and Reference Corchorus

Farms	As (mean±SD)	Cd (mean±SD)	Cu (mean±SD)	Pb (mean±SD)	Zn (mean ±SD)
1	BDL	0.38 ± 0.10	10.03 ± 0.03	2.53 ± 0.30	60.50 ± 2.00
2	BDL	0.55 ± 0.03	10.33 ± 0.05	4.70 ± 0.18	88.50 ± 3.50
3	BDL	0.39 ± 0.08	6.76± 0.03	1.54 ± 0.18	57.61 ± 1.05
4	BDL	0.28 ± 0.08	10.45 ±0.04	2.18 ± 0.45	18.25 ± 0.15

5	BDL	0.45 ± 0.10	8.83 ± 0.15	1.15 ± 0.15	39.25± 2.75
6	BDL	0.38 ± 0.01	8.75 ± 0.10	1.35 ± 0.18	57.50 ± 2.75
7	BDL	0.22 ± 0.01	2.53 ± 0.03	0.87 ± 0.01	51.60 ± 0.02
8	BDL	0.23 ± 0.01	9.82 ± 0.02	4.15 ± 0.02	23.00 ± 0.06
9	BDL	0.30 ± 0.10	3.41 ± 0.01	2.43 ± 0.01	40.22 ± 0.01
10	BDL	0.58 ± 0.08	7.60 ± 0.05	3.50 ± 0.30	57.50 ± 3.50
11	BDL	0.48 ± 0.08	7.78 ± 0.10	3.00± 0.13	50.00 ±2.50
12	BDL	0.30 ± 0.03	5.45 ± 0.10	2.70 ± 0.35	58.75 ± 1.00
13	BDL	0.30 ± 0.10	6.45 ± 0.08	2.85 ± 0.23	60.50 ± 1.75
14	BDL	0.10 ± 0.01	4.22 ±0.01	1.38± 0.01	25.60 ± 0.03
15	BDL	0.11 ± 0.01	10.08 ± 0.01	0.06 ± 0.01	14.12 ±0.01
Ref. cor	BDL	0.003±0.01	0.10 ± 0.01	0.20 ± 0.01	0.60 ± 0.14
Limit	0.43[a]	0.20[a]	40.00[a]	0.30[a]	50.00[a]
Limit	-	0.20[b]	20.00[b]	0.43[b]	50.00[b]

a = FAO/WHO (2002) permissible limit b = EU (2006) permissible limit Ref. Cor = reference corchorus
SD = standard deviation BDL = below detection limit
Farm 1= Owode-Ede, by the road side Farm 2 = outskirt of Ede
Farm 3= Ilo-Ajegunle Farm 4= Ila-Orangun, near an abandoned waste depot
Farm 5= Ila-Orangun Farm 6 = Ido-Ijesa, near fish ponds
Farm 7 = outskirt of Ile-Ife Farm 8= by the road side, along Ede-road, Ile-Ife
Farm 9 = along Osogbo/Ilie road Farm 10= Outskirt of Iwo town, near a waste depot
Farm 11= between Telemu and Iwo Farm 12= along Osogbo/Ikirun road
Farm 13= outskirt of Osogbo town Farm 14= along Ikirun/Inisha road
Farm 15= outskirt of Osogbo town

In soil and vegetable samples collected from all peri-urban farms studied, Aswas below detection limit. Heavy metals concentration in the soil of peri-urban farms were below the FAO/WHO (2002) and EU (2006) permissible levels for metals in agricultural soil. Cadmium concentrations in Amaranthus and Corchorus exceeded the permissible limit set by FAO/WHO and EU (2006) for Cd in leafy vegetablesexcept in Corchorus collected from farms 14 and 15. Zinc concentration in Amaranthus and Corchorus also exceeded these limits for Zn in leafy vegetables except in Amaranthus collected from farms 5 and 15 and Corchrous collected from farms 4, 5, 8, 9, 11 and 15 respectively.Concentrations of Pb in

Amaranthus and Corchorus exceeded the FAO/WHO and EU (2006) limits for Pb in vegetables while concentrations of Cu in Amaranthus and Corchorus were below the limits. Amaranthus had the highest concentration for all investigated heavy metals except Cu (Fig. 4.6). There was difference in heavy metals concentration in reference soil and vegetable samples compared to heavy metals concentration in soil and vegetable samplesfrom peri-urban farms with significant values ($P<0.05$).

4.5: Hierarchical Cluster Analysis of Heavy Metals in Peri-urban Farm Soils and Vegetables

The hierarchical cluster analysis using nearest neighbor approach produced five cluster diagramswhich are shown in Fig. 4.1-4.5.Hierarchical cluster analysis was executed to determine the correspondence between sampling stations in the study area. Cluster diagram based on all investigated metals classified peri-urban farms into two distinct clusters. Cluster 1 shows that farms 3, 4,8, 6 and 9 are closely related. Cluster 2 shows that farms 1, 2, 5,7, 10, 11,12, 13, 14 and 15 are also related. According to Cd, Cu, Pb and Zn concentrations, HCA categorized each peri-urban farm into four distinctive cluster diagramsbased on pollution magnitude.

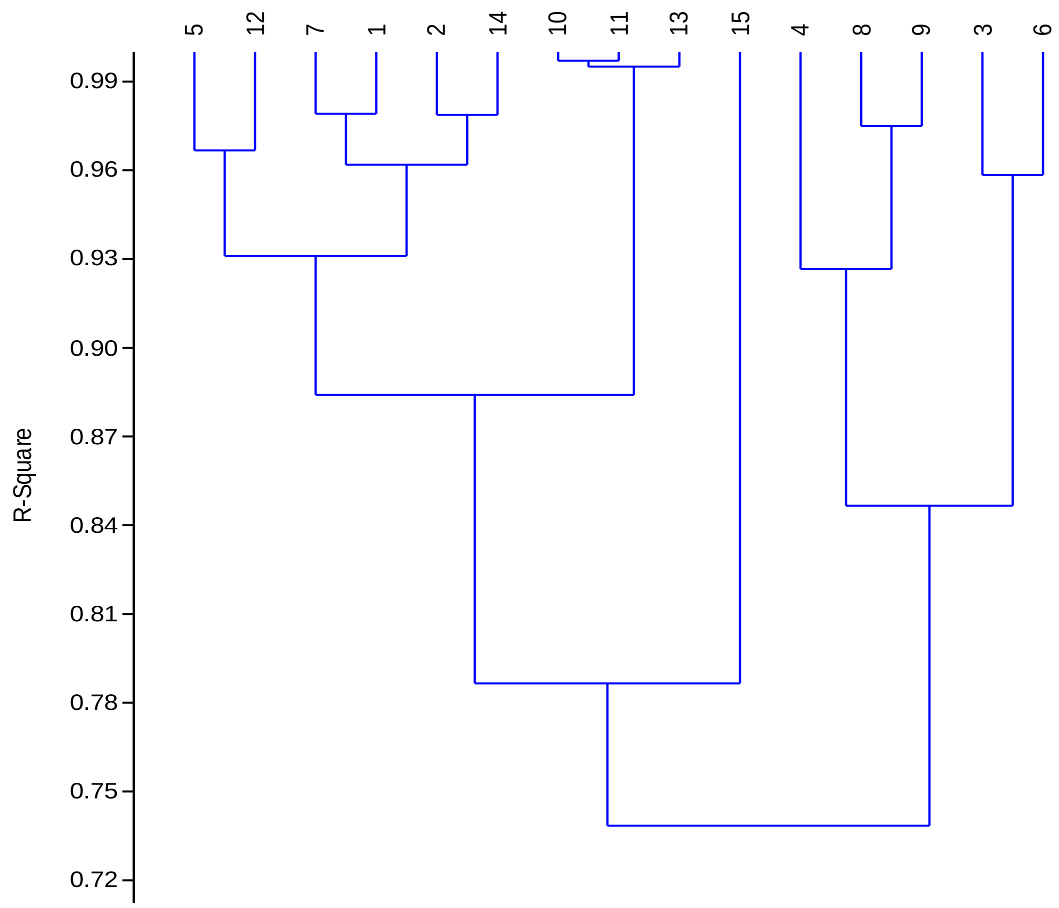

Fig 4.1: Cluster Diagram Based onAll Investigated Heavy Metals in Peri-urban Farm Soiland Vegetable Samples

LEGEND

Farm 1= Owode-Ede, by the road side
Farm 2 = outskirt of Ede
Farm 3= Ilo-Ajegunle
Farm 4= Ila-Orangun, near an abandoned waste depot
Farm 5= Ila-Orangun
Farm 6 = Ido-Ijesa, near fish ponds
Farm 7 = outskirt of Ile-Ife
Farm 8= by the road side, along Ede-road, Ile-Ife
Farm 9 = along Osogbo/Ilie road
Farm 10= Outskirt of Iwo town, near a waste depot
Farm 11= between Telemu and Iwo
Farm 12= along Osogbo/Ikirun road
Farm 13= outskirt of Osogbo town
Farm 14= along Ikirun/Inisha road
Farm 15= outskirt of Osogbo town

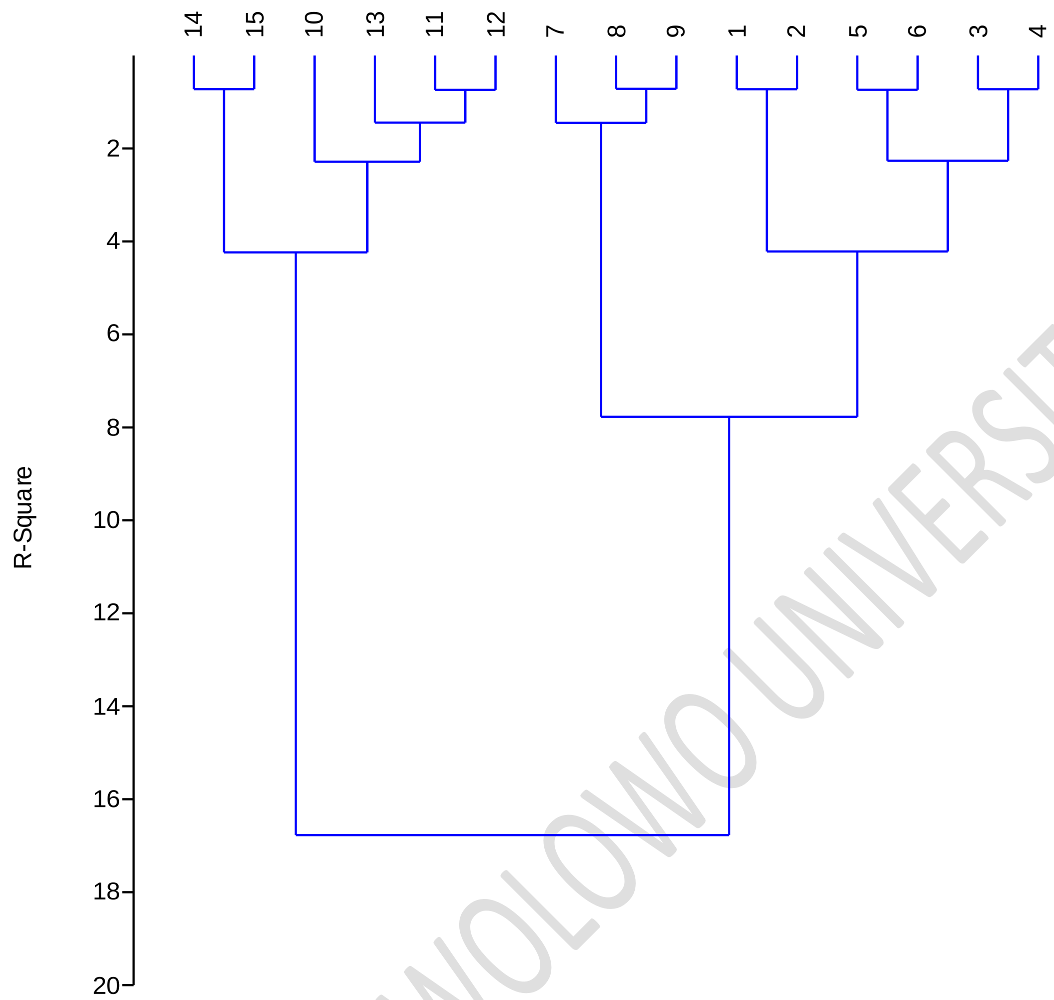

Fig 4.2: Cluster Diagram based on Cd Concentration in Peri-urban Farm Soil and Vegetable Samples

LEGEND

Farm 1= Owode-Ede, by the road side
Farm 2 = outskirt of Ede
Farm 3= Ilo-Ajegunle
Farm 4= Ila-Orangun, near an abandoned waste depot
Farm 5= Ila-Orangun
Farm 6 = Ido-Ijesa, near fish ponds
Farm 7 = outskirt of Ile-Ife
Farm 8= by the road side, along Ede-road, Ile-Ife
Farm 9 = along Osogbo/Ilie road
Farm 10= Outskirt of Iwo town, near a waste depot
Farm 11= between Telemu and Iwo
Farm 12= along Osogbo/Ikirun road
Farm 13= outskirt of Osogbo town
Farm 14= along Ikirun/Inisha road
Farm 15= outskirt of Osogbo town

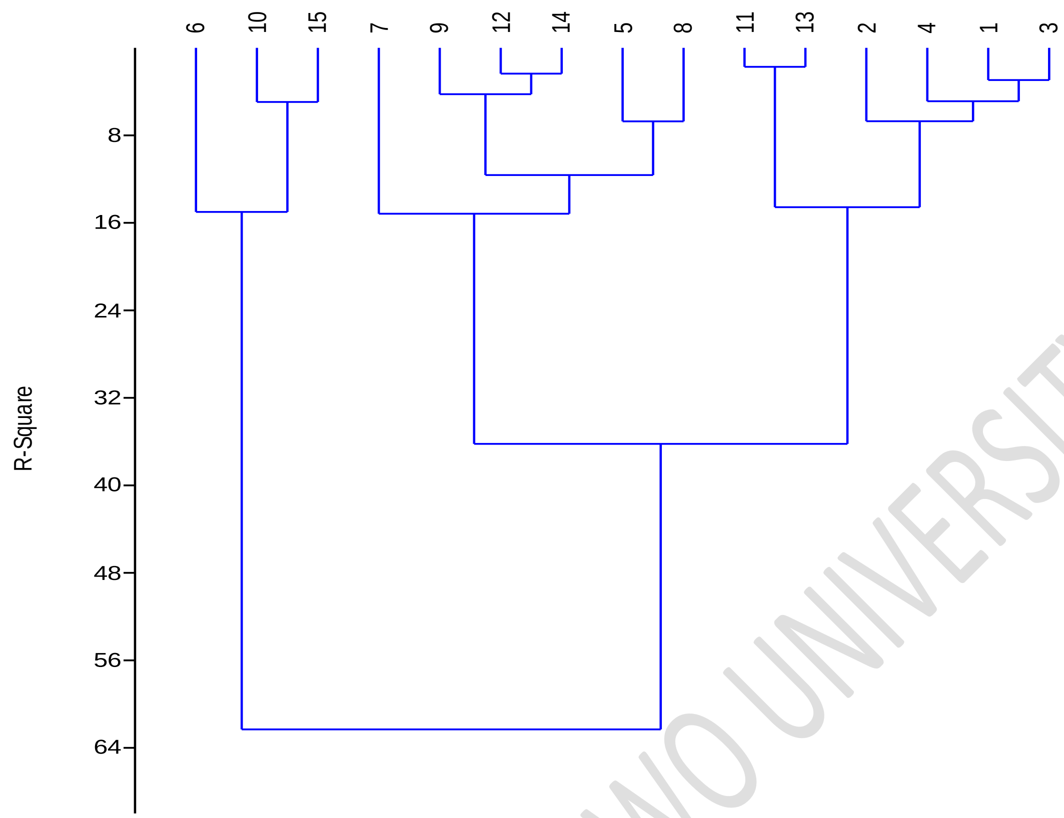

Fig 4.3: Cluster Diagram Based on Cu Concentration in Peri-urban Farm Soil and Vegetable Samples

LEGEND

Farm 1= Owode-Ede, by the road side
Farm 2 = outskirt of Ede
Farm 3= Ilo-Ajegunle
Farm 4= Ila-Orangun, near an abandoned waste depot
Farm 5= Ila-Orangun
Farm 6 = Ido-Ijesa, near fish ponds
Farm 7 = outskirt of Ile-Ife
Farm 8= by the road side, along Ede-road, Ile-Ife
Farm 9 = along Osogbo/Ilie road
Farm 10= Outskirt of Iwo town, near a waste depot
Farm 11= between Telemu and Iwo
Farm 12= along Osogbo/Ikirun road
Farm 13= outskirt of Osogbo town
Farm 14= along Ikirun/Inisha road
Farm 15= outskirt of Osogbo town

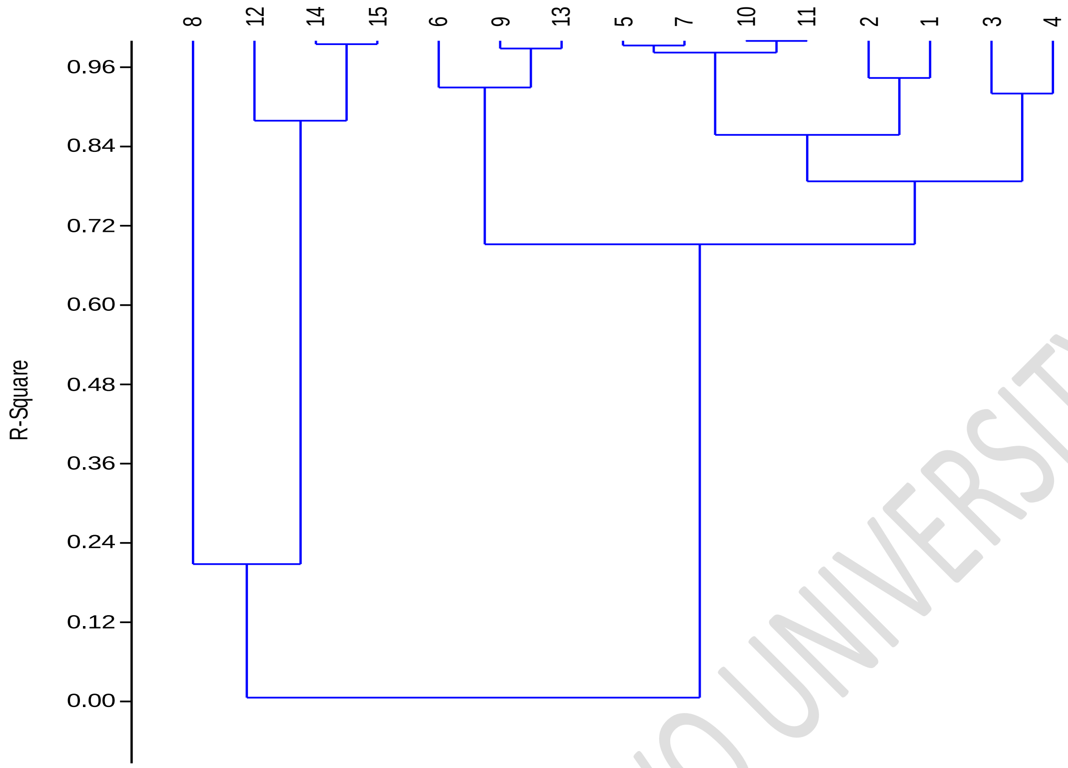

Fig 4.4: Cluster Diagram Based on Pb Concentration in Peri-urban Farm Soil and Vegetable Samples

LEGEND

Farm 1= Owode-Ede, by the road side
Farm 2 = outskirt of Ede
Farm 3= Ilo-Ajegunle
Farm 4= Ila-Orangun, near an abandoned waste depot
Farm 5= Ila-Orangun
Farm 6 = Ido-Ijesa, near fish ponds
Farm 7 = outskirt of Ile-Ife
Farm 8= by the road side, along Ede-road, Ile-Ife
Farm 9 = along Osogbo/Ilie road
Farm 10= Outskirt of Iwo town, near a waste depot
Farm 11= between Telemu and Iwo
Farm 12= along Osogbo/Ikirun road
Farm 13= outskirt of Osogbo town
Farm 14= along Ikirun/Inisha road
Farm 15= outskirt of Osogbo town

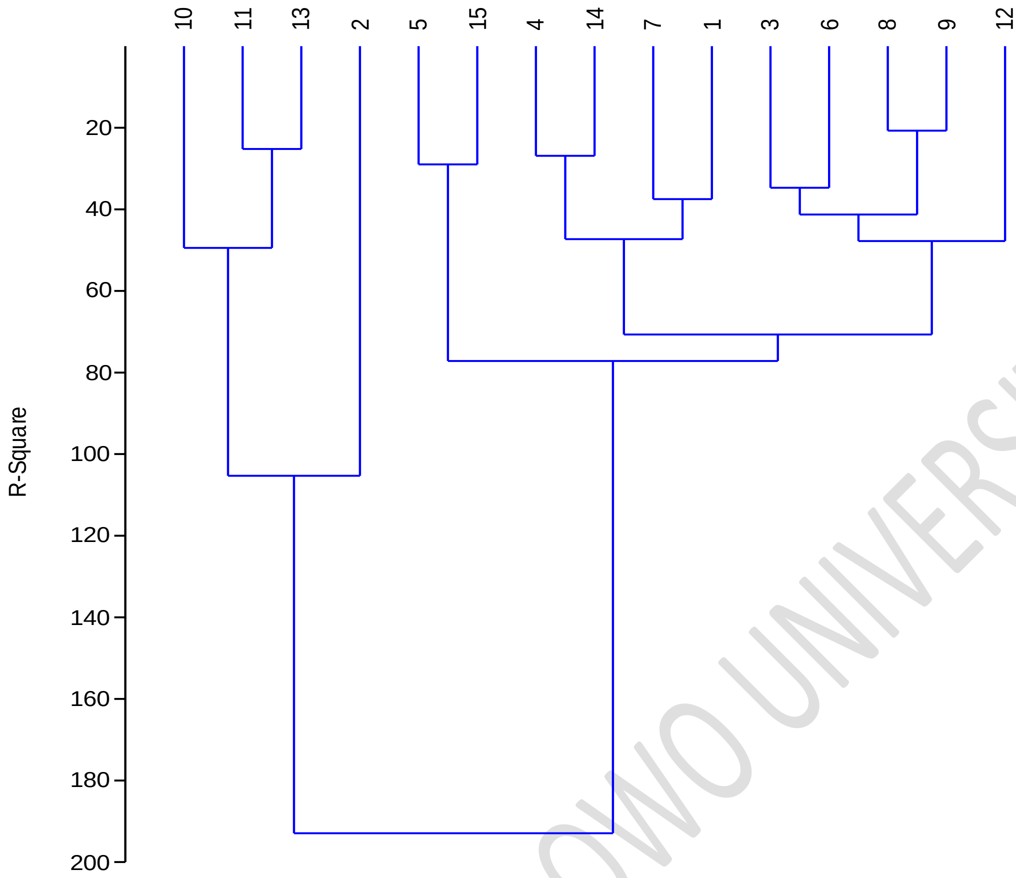

Fig 4.5: Cluster Diagram Based on Zn Concentration in Peri-urban Farm Soil and Vegetable Samples

LEGEND

Farm 1= Owode-Ede, by the road side
Farm 2 = outskirt of Ede
Farm 3= Ilo-Ajegunle
Farm 4= Ila-Orangun, near an abandoned waste depot
Farm 5= Ila-Orangun
Farm 6 = Ido-Ijesa, near fish ponds
Farm 7 = outskirt of Ile-Ife
Farm 8= by the road side, along Ede-road, Ile-Ife
Farm 9 = along Osogbo/Ilie road
Farm 10= Outskirt of Iwo town, near a waste depot
Farm 11= between Telemu and Iwo
Farm 12= along Osogbo/Ikirun road
Farm 13= outskirt of Osogbo town
Farm 14= along Ikirun/Inisha road
Farm 15= outskirt of Osogbo town

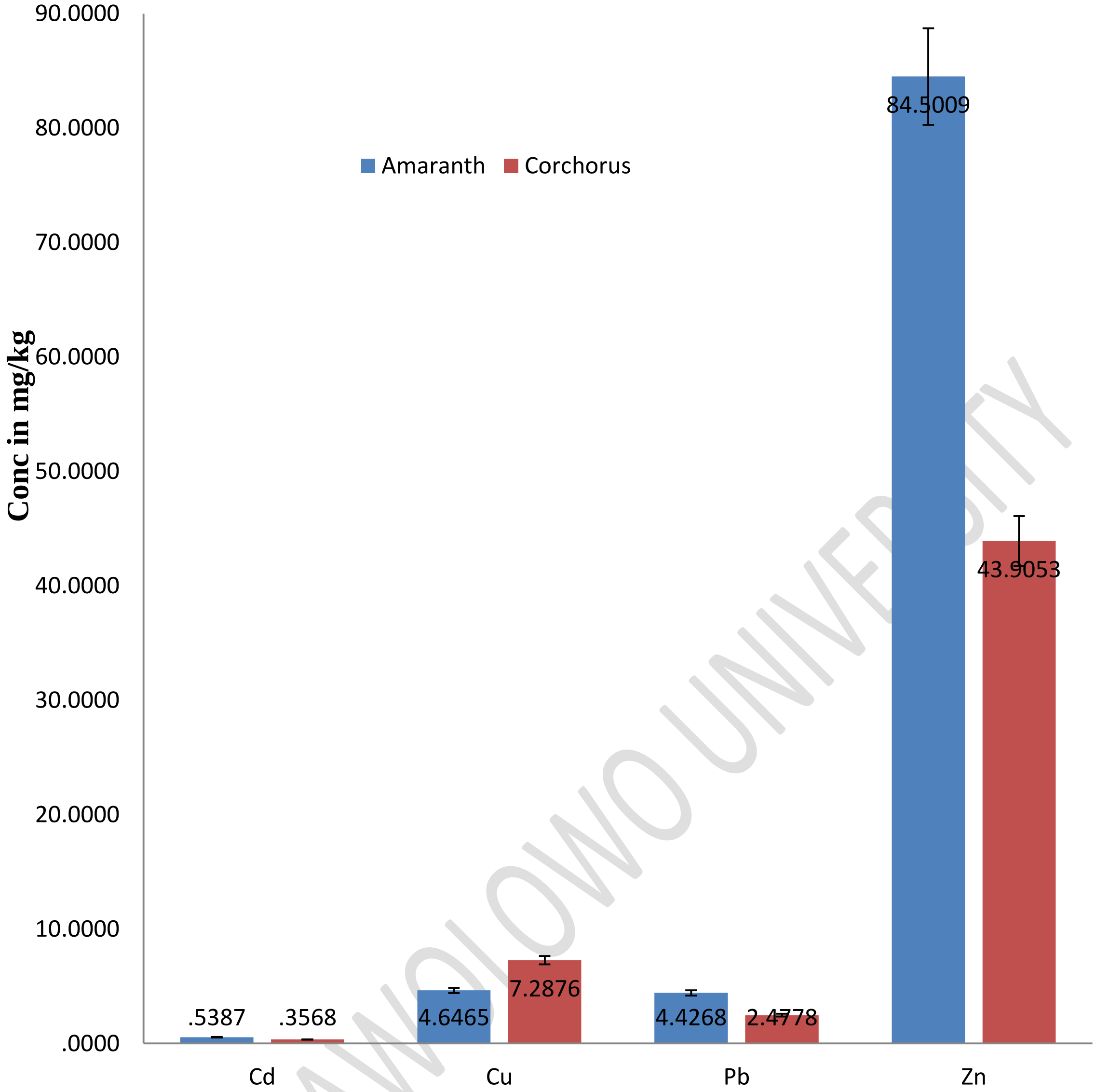

Fig 4.6: Comparison of Heavy Metals Uptake by Vegetables

4.6 Pollution Load Index (PLI)

Table 4.7 shows the result of the PLI for the five metals studied at the various farms. The PLI for Cd, Cu, Pb and Zn ranged from 1.51-5.25, 0.86-11.34, 0.15-8.02 and 0.44-6.49, respectively. The degree of contamination is in the order farm 10> 11 > 13> 1> 6 > 15> 2> 4> 7> 3> 5> 9> 8 >14 > 12. The soils of peri-urban farms studied were moderately enriched with Cd and Zn but strongly enriched with Cu and Pb.

4.7 Transfer Factor of Individual Metal to Vegetables (TF)

The transfer factor as computed indicated the level of metal in the edible plant as a fraction of the soil total. The plant transfer factor is presented in Tables 4.8 and 4.9. The transfer factor for Cd, Cu, Pb and Zn ranged from 0.07-4.44, 0.06-0.41, 0.07-4.28 and 0.31-4.08 mg/kg, respectively for Amaranthus while it ranged from 0.11-2.11, 0.06-2.27, 0.06-3.86 and 0.13-2.63 mg/kg, respectively for Corchorus. Cadmium had the highest transfer factor followed by Zn while Cu and Pb had the lowest. Transfer Factor values showed metal uptake by vegetables in the order Cd >Zn> Pb >Cu. Amaranthus had the highest TF for all metals except Cu. Table 4.10shows the test of correlation between heavy metals concentration in peri-urban farm soil and vegetable samples. Pearson correlation detected positive correlations which were statistically significant at ($p < 0.05$) between Cd, Pb and Zn concentrations in the soil of peri-urban farms studied. Pearson correlation also detected positive correlation between Cd, Pb and Zn concentration in Corchorus. Copper and Pb concentrations in Amaranthus and Corchorus also correlated significantly.

Table 4.7: Pollution Load Indexof Heavy Metals (PLI)

Farm	As	Cd	Cu	Pb	Zn
1	-	1.51	5.45	8.02	1.76
2	-	2.92	3.47	2.31	2.81
3	-	1.66	4.39	0.98	0.44
4	-	1.91	4.66	2.57	1.01
5	-	2.75	1.08	2.94	0.66
6	-	2.33	11.34	1.20	0.43
7	-	3.16	2.81	3.28	1.58
8	-	1.92	1.49	1.11	0.70
9	-	2.33	0.86	2.35	0.87
10	-	5.25	8.57	7.39	4.31
11	-	3.75	5.16	8.01	3.67
12	-	1.67	0.48	0.153	0.99
13	-	3.75	5.26	3.55	6.49
14	-	1.83	0.95	1.16	1.46
15	-	3.58	7.70	0.76	0.72

Farm 1= Owode-Ede, by the road side
Farm 2 = outskirt of Ede
Farm 3= Ilo-Ajegunle
Farm 4= Ila-Orangun, near an abandoned waste depot
Farm 5= Ila-Orangun
Farm 6 = Ido-Ijesa, near fish ponds
Farm 7 = outskirt of Ile-Ife
Farm 8= by the road side, along Ede-road, Ile-Ife
Farm 9 = along Osogbo/Ilie road
Farm 10= Outskirt of Iwo town, near a waste depot
Farm 11= between Telemu and Iwo
Farm 12= along Osogbo/Ikirun road
Farm 13= outskirt of Osogbo town
Farm 14= along Ikirun/Inisha road
Farm 15= outskirt of Osogbo town

Table 4.8: Transfer Factor of Individual Metal from Soil to *Amaranthus hybridus*(mg/kg)

Farm	TFAs	TFCd	TFCu	TFPb	TFZn
1	-	4.44	0.19	0.07	0.77
2	-	2.37	0.35	0.47	0.81
3	-	3.63	0.30	0.68	2.87
4	-	1.96	0.41	0.87	1.10
5	-	0.92	0.15	0.06	0.91
6	-	2.09	0.06	0.38	4.08
7	-	0.73	0.09	0.08	0.56
8	-	3.04	1.30	2.26	2.20
9	-	2.00	0.85	0.24	1.78
10	-	0.34	0.12	0.35	0.35
11	-	1.05	0.18	0.12	0.40
12	-	2.75	1.75	4.28	1.11
13	-	0.78	0.18	0.07	0.31
14	-	0.56	0.75	0.26	0.83
15	-	0.50	0.14	0.01	0.86

Farm 1= Owode-Ede, by the road side
Farm 2 = outskirt of Ede
Farm 3= Ilo-Ajegunle
Farm 4= Ila-Orangun, near an abandoned waste depot
Farm 5= Ila-Orangun
Farm 6 = Ido-Ijesa, near fish ponds
Farm 7 = outskirt of Ile-Ife
Farm 8= by the road side, along Ede-road, Ile-Ife
Farm 9 = along Osogbo/Ilie road
Farm 10= Outskirt of Iwo town, near a waste depot
Farm 11= between Telemu and Iwo
Farm 12= along Osogbo/Ikirun road
Farm 13= outskirt of Osogbo town
Farm 14= along Ikirun/Inisha road
Farm 15= outskirt of Osogbo town

Table 4.9: Transfer Factor of Individual Metal from Soil to *Corchorus olitorious* (mg/kg)

Farm	TFAs	TFCd	TFCu	TFPb	TFZn

1	-	2.11	0.37	0.06	2.63
2	-	1.57	0.60	0.44	0.45
3	-	1.96	0.31	0.34	1.88
4	-	1.22	0.45	0.19	0.19
5	-	1.22	1.65	0.97	0.85
6	-	1.36	0.16	0.08	1.92
7	-	0.40	0.18	0.06	0.47
8	-	1.00	1.33	0.81	0.47
9	-	0.11	0.06	0.32	0.66
10	-	0.92	0.18	0.15	0.19
11	-	0.94	0.30	0.08	0.20
12	-	1.50	2.27	3.86	0.85
13	-	0.67	0.25	0.18	0.13
14	-	0.45	0.26	0.29	0.25
15	-	0.25	0.26	0.19	0.28

Farm 1= Owode-Ede, by the road side
Farm 2 = outskirt of Ede
Farm 3= Ilo-Ajegunle
Farm 4= Ila-Orangun, near an abandoned waste depot
Farm 5= Ila-Orangun
Farm 6 = Ido-Ijesa, near fish ponds
Farm 7 = outskirt of Ile-Ife
Farm 8= by the road side, along Ede-road, Ile-Ife
Farm 9 = along Osogbo/Ilie road
Farm 10= Outskirt of Iwo town, near a waste depot
Farm 11= between Telemu and Iwo
Farm 12= along Osogbo/Ikirun road
Farm 13= outskirt of Osogbo town
Farm 14= along Ikirun/Inisha road
Farm 15= outskirt of Osogbo town

4.8 Estimated Daily Intake of Metals (DIM)

The estimated daily intake of metals through the food chain for adult is given in Tables 4.11and 4.12. The estimated daily intake of Cd, Cu, Pb and Zn from consumption of

Amaranthus ranged from 0.0003-0.001, 0.00021-0.016, 0.002-0.014 and 0.053-0.159 mg/kg/day, respectively and ranged from 0.0002-0.0016, 0.004-0.016, 0.0017-0.0076 and 0.023-0.144 mg/kg/day, respectively from consumption of Corchorus .The highest intake of Cd, Cu, Pb and Zn were from consumption of Amaranthus. The estimated DIM when compared to recommended daily intake/ allowance for heavy metals (USEPA, 2009) was below the recommended daily intake/ allowance for metals studied.

4.9 Potential Health Risk Index (HRI) and Hazard Index (HI)

The potential health risk of heavy metals through consumption of vegetables is presented in Tables 4.13 and 4.14. The HRI for Cd, Cu, Pb and Zn from consumption of Amaranthus ranged from 0.30-1.20, 0.03-0.38, 0.10-4.75 and 0.18-0.86, respectively while it ranged from 0.20-0.90, 0.10-0.43, 0.35-1.68 and 0.08-0.48, respectively for consumption of Corchorus. The result showed high values for Cd and Pb and low values for Cu and Zn. The HRI for Cd and Pb from consumption of Amaranthus was greater than 1 in farms 1, 2, 3, 8 and farms 1, 2, 3, 4, 8, 9, 10, 11, 12, respectively. Health risk index for Pb from consumption of Corchorus was greater than 1 in farms 1, 2, 8, 10, 11, 12 and 13. The calculated hazard indexfor all the assayed heavy metals in Amaranthus and Corchorus from all the peri-urban farms studied was greater than 1.

Table 4.11: Daily Metals Intake Estimate (mg^{-1} kg^{-1} $person^{-1}$ d^{-1}) from Consumption of*Amaranthus hybridus* in Adults

Farm	As	Cd	Cu	Pb	Zn
1	-	0.0010	0.0080	0.0040	0.1550
2	-	0.0010	0.0100	0.0080	0.2590

3	-	0.0012	0.0110	0.0050	0.1430
4	-	0.0009	0.0150	0.0140	0.1760
5	-	0.0005	0.0010	0.0013	0.0680
6	-	0.0009	0.0054	0.0030	0.2010
7	-	0.0005	0.0021	0.0019	0.1009
8	-	0.0011	0.0160	0.0190	0.1780
9	-	0.0009	0.0060	0.0040	0.1760
10	-	0.0003	0.0085	0.0079	0.1715
11	-	0.0008	0.0070	0.0073	0.1657
12	-	0.0009	0.0069	0.0050	0.1245
13	-	0.0006	0.0078	0.0017	0.1260
14	-	0.0003	0.0057	0.0040	0.1388
15	-	0.0004	0.0070	0.0053	0.0900
RDI	-	0.0640	10.000	0.2400	40.000

RDI-Recommended daily intake/ allowance for heavy metals in mg/day

Farm 1= Owode-Ede, by the road side
Farm 2 = outskirt of Ede
Farm 3= Ilo-Ajegunle
Farm 4= Ila-Orangun, near an abandoned waste depot
Farm 5= Ila-Orangun
Farm 6 = Ido-Ijesa, near fish ponds
Farm 7 = outskirt of Ile-Ife
Farm 8= by the road side, along Ede-road, Ile-Ife
Farm 9 = along Osogbo/Ilie road
Farm 10= Outskirt of Iwo town, near a waste depot
Farm 11= between Telemu and Iwo
Farm 12= along Osogbo/Ikirun road
Farm 13= outskirt of Osogbo town
Farm 14= along Ikirun/Inisha road
Farm 15= outskirt of Osogbo town

Table 4.12: Daily Metals Intake Estimate (mg^{-1} kg^{-1} $person^{-1}$ d^{-1}) from Consumption of *Corchorus olitorious* in Adults

Farm	As	Cd	Cu	Pb	Zn
1	-	0.0006	0.0160	0.0041	0.0920
2	-	0.0008	0.0168	0.0076	0.1440

3	-	0.0006	0.0110	0.0025	0.0920
4	-	0.0004	0.0170	0.0035	0.0290
5	-	0.0007	0.0140	0.0019	0.0640
6	-	0.0006	0.0140	0.0022	0.0940
7	-	0.0004	0.0040	0.0014	0.0843
8	-	0.0004	0.0160	0.0067	0.0380
9	-	0.0004	0.0060	0.0039	0.0660
10	-	0.0009	0.0120	0.0057	1.0939
11	-	0.0008	0.0127	0.0049	0.0820
12	-	0.0005	0.0089	0.0044	0.0960
13	-	0.0005	0.0140	0.0045	0.0990
14	-	0.0002	0.0068	0.0023	0.0420
15	-	0.0002	0.0160	0.0017	0.0230
RDI	-	0.0640	10.000	0.2400	40.000

RDI-Recommended daily intake/ allowance for heavy metals in mg/day

Farm 1= Owode-Ede, by the road side
Farm 2 = outskirt of Ede
Farm 3= Ilo-Ajegunle
Farm 4= Ila-Orangun, near an abandoned waste depot
Farm 5= Ila-Orangun
Farm 6 = Ido-Ijesa, near fish ponds
Farm 7 = outskirt of Ile-Ife
Farm 8= by the road side, along Ede-road, Ile-Ife
Farm 9 = along Osogbo/Ilie road
Farm 10= Outskirt of Iwo town, near a waste depot
Farm 11= between Telemu and Iwo
Farm 12= along Osogbo/Ikirun road
Farm 13= outskirt of Osogbo town
Farm 14= along Ikirun/Inisha road
Farm 15= outskirt of Osogbo town

Table 4.13: Potential Health Risk and Hazard Index of Heavy Metals through Intake of *Amaranthus hybridus* in Adult

Farm	As	Cd	Cu	Pb	Zn	HI
1	-	1.00	0.21	1.00	0.52	2.73
2	-	1.00	0.24	2.03	0.86	4.13

3	-	1.20	0.28	1.25	0.48	3.21
4	-	0.90	0.38	3.50	0.59	5.37
5	-	0.49	0.03	0.33	0.22	1.07
6	-	0.95	0.14	0.75	0.67	2.51
7	-	0.50	0.05	0.48	0.33	1.36
8	-	1.10	0.40	4.75	0.59	6.84
9	-	0.90	0.15	1.00	0.22	2.27
10	-	0.30	0.21	1.98	0.57	3.06
11	-	0.80	0.18	1.83	0.55	3.36
12	-	0.90	0.17	1.25	0.42	2.74
13	-	0.60	0.20	0.43	0.42	1.65
14	-	0.30	0.14	0.10	0.46	1.00
15	-	0.40	0.18	0.13	0.30	1.01

HI = hazard index

Farm 1= Owode-Ede, by the road side
Farm 2 = outskirt of Ede
Farm 3= Ilo-Ajegunle
Farm 4= Ila-Orangun, near an abandoned waste depot
Farm 5= Ila-Orangun
Farm 6 = Ido-Ijesa, near fish ponds
Farm 7 = outskirt of Ile-Ife
Farm 8= by the road side, along Ede-road, Ile-Ife
Farm 9 = along Osogbo/Ilie road
Farm 10= Outskirt of Iwo town, near a waste depot
Farm 11= between Telemu and Iwo
Farm 12= along Osogbo/Ikirun road
Farm 13= outskirt of Osogbo town
Farm 14= along Ikirun/Inisha road
Farm 15= outskirt of Osogbo town

Table 4.14: Potential Health Risk and Hazard Index of Heavy Metals through Intake of *Corchorus olitorius* in Adult

Farm	As	Cd	Cu	Pb	Zn	HI
1	-	0.60	0.40	1.03	0.31	2.30
2	-	0.80	0.42	1.90	0.48	3.60

3	-	0.64	0.28	0.63	0.31	1.86
4	-	0.40	0.43	0.88	0.09	1.80
5	-	0.70	0.35	0.48	0.21	1.74
6	-	0.60	0.35	0.55	0.31	1.81
7	-	0.40	0.10	0.35	0.30	1.15
8	-	0.40	0.40	1.68	0.13	2.61
9	-	0.40	0.15	0.98	0.22	1.75
10	-	0.90	0.30	1.43	0.31	2.94
11	-	0.80	0.32	1.23	0.27	2.62
12	-	0.50	0.22	1.10	0.32	2.14
13	-	0.50	0.28	1.13	0.27	2.24
14	-	0.20	0.17	0.58	0.32	1.09
15	-	0.20	0.40	0.43	0.08	1.11

HI = hazard index
Farm 1= Owode-Ede, by the road side
Farm 2 = outskirt of Ede
Farm 3= Ilo-Ajegunle
Farm 4= Ila-Orangun, near an abandoned waste depot
Farm 5= Ila-Orangun
Farm 6 = Ido-Ijesa, near fish ponds
Farm 7 = outskirt of Ile-Ife
Farm 8= by the road side, along Ede-road, Ile-Ife
Farm 9 = along Osogbo/Ilie road
Farm 10= Outskirt of Iwo town, near a waste depot
Farm 11= between Telemu and Iwo
Farm 12= along Osogbo/Ikirun road
Farm 13= outskirt of Osogbo town
Farm 14= along Ikirun/Inisha road
Farm 15= outskirt of Osogbo town

CHAPTER FIVE

DISCUSSION

The soil pH is one of the most indicative measurements of the general chemical status of soil. The soil pH is typically measured as soil solution pH, it is also an indicator of the proportions of basic and acidic exchangeable ions present in the soil (USDA, 1999). This is because these ions in the soil solution are in equilibrium with the exchangeable ions. The pH affects the mobility of heavy metals in soil. It has been found that soil pH is correlated with the availability of nutrients to plant (Gray *et al.*, 1998). Consequently, as pH decreases, the solubility of metallic elements in the soil increases and they become more readily available to plants (Smith, 1996; Oliver *et al.*, 1998; Salam and Helmke, 1998). Heavy metal mobility decreases with increasing soil pH due to precipitation of hydroxides, carbonates formation of insoluble organic complexes. Heavy metals are generally more mobile at pH < 7than at pH >7. The amount of metals mobilized in soil environment is a function of pH, properties of metals, redox condition, soil chemistry, organic matter content and other soil properties (Anem *et al.*, 1998; Kemberly and Williams, 1999; Saure *et al.*, 2000).

Neutral pH would favour availability, mobility and redistribution of metals in the various fractions due to increase solubility of ions in neutral environment (Oviasogie and Ndiokwere, 2008). In this study, the pH ranged between 5.24-7.87 (moderately acidic to slightly alkaline). It was observed that where soil pH was recorded near neutral, low concentration of heavy metals was recorded in vegetables than in soil except for Cd. This high Cd content might be due to vegetables accumulating Cd from manure through foliar absorption. This observation was consistent in farms where inorganic fertilizer and poultry manure were used to maintain soil fertility. This contrasts with the higherCd uptake by vegetables from soil at low pH of soil (Akinola *et al*, 2008; Alchaerani *et al.*, 2009).

The presence of organic carbon increases the cation exchange capacity of the soil which retains nutrients assimilated by plants (Agbede, 2009). Total organic carbon in the soil of peri-urban farms under investigation ranged from 0.68-6.32%. The total organic carbon were low to high based on classification of soil % OC given by Enwezor *et al.* (1998) in the present study suggesting a possibility of metals retention within the soil. The high amount of organic carbon in some of the peri-urban farms studied (Farms 3 and 8) is suggestive of degradation or presence of degradable and compostable wastes (Munoz *et al*., 1994).

Soil organic matter enhances the usefulness of soils for agricultural purposes. It supplies essential nutrient and has unexcelled capacity to hold water and absorb cations. It also functions as a source of food for soil microbes and thereby helps to enhance and control their activities (Brady, 1999). Organic matter in the soil samples of peri-urban farms studied varied from 1.18 -10.87 %. Soils of peri-urban farms contain high amount of organic matter which could be as a result of agricultural applications. Ayolagba and Onmigbuta (2001) demonstrated that high organic matter (>2.0%) in soil is conducive for heavy metals chelation.

Of all the 16 essential plant nutrient elements needed for plant growth, development and reproduction, nitrogen (as nitrate or ammonia) is the most vital and most limiting throughout the world (Agbede, 2009). Animal and man depend on protein manufactured by plants from nitrogen which could be regarded as the key nutrient in plant growth. Nitrogen gas which accounts for about 78% of atmospheric gas has to be converted to two utilizable forms by plants before it can be regarded as useful to plants. These two forms are the cation form, ammonium ion (NH_4^+) and the anion form (NO_3^-). The available $NO_3^-$is supplied from aerobic decomposition of soil organic matter or added to the soil as chemical nitrogen fertilizers. Nitrate represents the most oxidized form of nitrogen found in natural systems. It is often regarded as an unambiguous indicator of domestic and agricultural pollution. In soil samples, it is formed primarily as a result of oxidation of NH_4^+ to NO_2^- and subsequently, to $NO_3^-$by nitrication process.

In this study,the percentage nitrogen content of peri-urban farm soils ranged from 0.06-0.54% while nitrate level varied between 20.45-240.52 mg/kg.According to Ideriah, *et* *al*. (2006), low value of nitrogen content may be attributed to high decomposition and efficient mineralization process. Uwah *et al*. (2009) also reported nitrate level of 311.55-398.65µg/g in soil samples irrigated with waste water obtained from Maiduguri, Nigeria.

Nitrate is formed from fertilizers,decaying plants, manure and other organic residues.It is found in the air, soil, water and food (particularlyin vegetables) and is produced naturally within thehuman body (Walker, 1990; Gangolli *et al*., 1994). It is also used as food additive,mainly as a preservative and antimicrobial agent (Speijer *et al*.,2003). Due to the increased use of synthetic nitrogen fertilizers and livestock manure in intensive agriculture, vegetables and drinking water may contain higher concentrations of nitrate than in the past.Vegetables are the major sources of the daily intake of nitrate by human beings,supplying about 72 to 94% of the total intake (Ditch,*et al*.,1996). The presence of nitrate in vegetables, and generally in other foods, is a serious threat to man's health. Nitrate per se is relatively non-toxic (Speijer *et al*., 2004; Mesinga *et al.*, 2003) but approximately 5% of all ingested nitrate is converted in saliva and the gastrointestinal tract to the more toxic nitrite (Spiegelholder *et al*., 1979). The only chronic toxic effects of nitrate are those resulting from the nitrite formed by its reduction by bacterial enzymes (Mesinga *et al*., 1976).

Nitrate concentration in vegetables from peri-urban farms ranged from 214.15-1,204.50 mg/kg which is within the permissible limit for nitrate in leafy vegetables (2500-3000 mg/kg) set by WHO/EC (1993).The levels of the anionin the leafy vegetables investigated were in agreement with the fact that leafy vegetables such as spinach contain nitrate at significant levels and that vegetables such as beetroot, lettuce and radish often contain nitrate concentrations above 2500 mg/kg (Maynard*et al.,* 1976).The variation observed in concentrations of nitrate in vegetables of peri-urban farms could be attributed to differences in anthropogenic activities, likedifferent farming practices such as usage of fertilizers,manureand other agrochemicals(Catfineld *et al.*,1973; Maynard *et al.*,1976) as well as the use of waste water and all kinds of polluted water in irrigating the soils. This could also be attributed to a number of environmental factors such as drought, day light intensity, and soil temperature and soil type (Gangolli *et al.*,1994;FAO/WHO, 1995). The result obtained in this study is similar to those observed by Nwachukwu *et al.*(2015) who reported nitrate concentration of 2,485μg/g and 938.76μg/g in *Amaranthus viridi*s and *Vernonia amygdalina* respectivelyand also to the work of Uwah *et al.*(2009) who also reported nitrate level of 476-8,920μg/g in vegetables obtained in Maiduguri, Nigeria.

The distribution of metals in soils of peri-urban farms studied was mainly affected by location of the peri-urban farm, prevailing agronomic practices and source of water for irrigation. Peri-urban farms located by the roadside, near waste depots and irrigated with waste water showed the highest level of contamination.

Anthropogenic addition of Cd to soil occurs via short-or long-range atmospheric deposition, addition in fertilizers/manure, municipal sewage wastes (effluents and biosolids), urban composts and industrial sludge (Taylor, 1997). Atmospheric Cd is derived from mining and smelting of non-ferrous metals, the production of iron and steel, combustion of fossil fuels and waste incineration. In fertilizers, Cd is found predominantly in phosphate fertilizers due to its presence as impurity in phosphate rocks. The contribution of atmosphere, fertilizer, sludge, manure or compost to total annual Cd addition to soils varies widely among the countries and regions of the world. (Jensen and Bro-Rasmussen, 1992;Kghlin *et al*.,1996). In less industrialized agricultural regions or countries (e.g Nigeria), atmospheric deposition is minimal. Cadmium is an important toxic heavy metal and the warning of health risks from Cd pollution was issued initially in the 1970s (Taylor, 1997). Increased accumulation of Cd in agricultural soils are known to come from human activities (Taylor, 1997) such as the application of phosphate fertilizers, sewage sludge, waste water and pesticides (Kara *et al*., 2004), from traffic emission and tear and wear of alloyed parts of vehicles.

Concentration of Cd in the soils of various peri-urban farms studied ranged from 0.18-0.63 mg/kg. These values were far lower than the natural limit of 3.0-5.0 mg/kg in soil as given by FAO/WHO (2002), EU (2006),EC (1986) and MAFF (1992). High concentration of Cd in the soil of farm 10 may be due to metals mobility from a nearby waste depot while high level of Cd in the soils of farms 11 and 13 might come from agricultural applications (irrigation water source or the use of inorganic fertilizer as soil amender).The values of Cd concentrations obtained from the soil of peri-urban farms investigated are far below the maximum tolerable levels proposed for agricultural soils. This is in agreement with the findings of Asawalam and Eke (2006), Njoku and Ayoka (2007), Oluyemi *et al*. (2008) and Oyekunle *et al*. (2001) who investigated trace metal concentration and heavy metal pollutants from dump and agricultural soils in Owerri, Ile-Ife and Osogbo, Nigeria.

Copper is added to the diet of some growing animals at levels up to 250 ppmto increase their growth rate and promote feed conversion efficiency. Manure produced by these animals containshigh concentrations of Cu. The application of this manure to agricultural soil produces an increase in soil Cu concentration (Mullins *et al*.,1982). In excess, elevated levels of Cu can become toxic to plants, can adversely affect organisms that feed on these plants, and can enter water system through surface run- off and leaching (Gupta and Charles, 1999). Copper can also be introduced into poultry diets involuntarily through contaminated feed stuffs or in much greater proportions as veterinary medicines or growth promoters.

According to Alloway (1990) and Lenntech (2009), copper strongly attaches to organic matter and minerals in soils. As aresult, it does not travel very far after release. As a result of the limited mobility, applied Cu tends to accumulate in soil (Slooff *et al*., 1989). In this study, concentration of Cu in the investigated soil samples varied between 2.40-56.17 mg/kg. Soil samples collected from farm 6 and 10 had the highest concentration. Elevated levels of copper in Farm 6 could be traced to the use of Cu as additive in fish pellet (Bolan *et* *al.*, 2004) which might have leached into the farmwhile the elevated level of Cu observed in farm 10 could be traced to leaching from a nearby waste depot. The concentrations of Cu in the current study were lower than those recorded in soil samples of Torino (171.00µg/g)by Biasioli *et al*. (2007) and Guang-dong (576.50 µg/g) by Zhou*et al*. (2007).However, the values obtained are compatible with the values obtained in a Canadian soil in which average Cu concentration was estimated to be 20 mg/kg, with a range between 2 and 100 mg/kg (British Columbia Ministry of Environment, Lands and Parks, 1992).

Lead is ranked as one of the most serious pollutant among the toxic heavy metals, which has been used by mankind for several years because of its wide variety of applications and considered as one of the most toxic metals affecting man, animal and plant (Zude, 2000). Humans are exposed to Pb from various sources and a myriad of pathways like air, water, dust, soil, food, homes and workplace (Zude, 2000). Lead has toxic properties and is found in large amount in many electronic devices (Nordic Council of Ministers, 1995), it is a major constituent of lead acid battery extensively used in car batteries and tyres which can end up in soil through corrosion.

Depending on the source of waste, addition of poultry waste to agricultural soils unconsciously points towards the build-up of heavy metals like Pb in soil (Alloway, 1995). Long term use of these biosolids on agricultural lands often results in the build up of elevated levels of heavy metals such as Pb in soils (Alloway, 1995). In addition, in countries such as Nigeria where there is high demand for food, contaminated arable land is used for crops. Increasing concern for lack of suitable land for agriculture has prompted peri-urban farmers to use contaminated land such as dump sites, major setback on the highways to produce food crops. Thus, peri-urban agriculture practiced widely in developing countries can be of great risk due to proximity of these contaminant sources (Garcia and Millan, 1998). In peri-urban agriculture, wastewater and solid organic wastes are often the main sources of water and fertilizer used to enhance the yields of staple crops and vegetables. This way, municipal or industrial effluents and solid waste often rich in trace metals, contribute significantly to metal loadings in irrigated and waste amended peri-urban soils.

The concentration of lead in the investigated soil samples ranged from 0.70-36.75 mg/kg. In this study, soil samples from farms 1, 10 and 11 had the highest Pb concentration. High Pb concentration observed in farm 1 might be due to past atmospheric deposition derived from combustion of gasoline as a result of the farm's proximity to a highway. High concentration of Pb observed in Farm 10 and 11 could be from irrigation water source or as a result of metalsmobility from a nearby waste depot to the farm through leaching and run –off. Lead levels obtained from this study were lower than those detected in British, England and Wales. Alloway (1995) mentioned that the total Pb content of normal British soil ranged from 2 to 300µg/g.By considering the general range of the Pb content, it appears that the total Pb content in soils of peri-urban farms studied were below the critical concentration of 300 mg/kg (FAO/WHO, 2002) and 400 mg/kg (ICRCL, 1987).

Zincis included in feed as growth enhancer which may have the ability to cause metal pollution of the soil (Chaney and Oliver, 1996; Summer, 2000). Some animal wastes like livestock, poultry and pig manure created in agriculture are usually supplied to crops and meadows either in the form of solids or semi solids (Summer, 2000). The supply of various biosolids, for example, composts, poultry manure and municipal sewage sludge to land could unconsciously contribute towards the build-up of heavy metals in the soil (Basta *et al.*, 2005). The manure that is created from animals as a result of their diet possesses greater amount of As, Cu, Fe, and Zn and if continually supplied to land, can result in reasonable accumulation of this metal in the longer period of time in the soil.

Zinc is used in break lining because of their heat conducting properties and as such released during mechanical abrasion of vehicles, from engine oil combustion and tyres of motor vehicles which are emitted into the environment as particles during deposition.

In this study, Zn concentration ranged between 30 to 300 mg/kg with farms 10 and 13 having the highest concentrations. High concentration of Zn observed in farm 10 might be due to proximity of the farm to a waste depot from which zinc might have leached into the farm or could also come from irrigation water source. High concentration of Zn observed in farm 13 might come from herbicide application or irrigation water source. Normal concentration of Zn in soil ranges from 1 to 300 mg/kg (FAO/WHO, 2002). Mcgrath (1986) reported that the Zn concentration in the soil of England and Wales ranged from 5 to 3,648 mg/kg. In this study, Zn concentration is lower than this range. Ogundele *et al.* (2005) reported Zn concentration of between 30.8 to 219.23 mg/kg in soils collected along heavy traffic road which is similar to values obtained in this study.

In this study, concentration of Arsenic was recorded below detection limit in almost all soil samples investigated. Heavy metal levels in the control/ reference soil were within the background level range for farming. Concentration of heavy metals in the soils of peri-urban farms were higher compared to heavy metals concentration in the reference soil indicating some degree of pollution in peri-urban farms. The concentration of heavy metals in the soil varied widely between farms as a result of different agronomic practices employed. The concentration of assayed heavy metals inall peri-urban farms studied were within the permissible level for agricultural soil. Even though heavy metal level fell below the critical level, it seems that its persistence in the soil of peri-urban farms may lead to increase uptake by plants.

Heavy metal concentration showed variation among vegetables collected from peri-urban farms. The variation in heavy metal concentrations in the vegetables of the same farm may be ascribed to the differences in their morphology and physiology for heavy metal uptake, exclusion, accumulation and retention (Kumar *et al.,* 2009). Vegetables differ in their ability to accumulate and concentrate metals in their edible parts, differences between them were numerically significant which was well supported from studies carried out by Sharma *et al.* (2006). The uptake and bioaccumulation of heavy metals in vegetables are influenced by many factors such as atmospheric deposition, concentrations of heavy metals in the soil, the nature of soil and degree of maturity of the plants at the time of harvest (Voutsa *et al*., 1996). Concentration of heavy metals analysed in vegetables also varied from one farm to the other which might be due to differences in farming practices.

In Amaranthus, the concentration of heavy metals ranged between 0.19 -0.83 mg/kg for Cd, 0.85-9.60 mg/kg for Cu, 0.80-11.55 mg/kg for Pb and 32.0 -158.8 for Zn respectively. In Corchorus, heavy metals concentration varied between 0.10-0.58mg/kg for Cd, 2.18-10.33 mg/kg for Cu, 0.87-4.70 mg/kg for Pb and 14.12-88.50 mg/kg for Zn respectively.The values of As were below detection limit in vegetables studied. The maximum accumulation of Cd was found in Amaranthus(0.49 mg/kg). Cd concentration in amaranthus and Corchorus exceeded the permissible limits prescribed by FAO/WHO and EU (2006) for Cd concentration in leafy vegetables except in Corchorus collected from farms14 and 15. Cadmium level measured in vegetables of peri-urban farms studied was lower than vegetables (10.37-17.79 mg/kg) from Titagarh West Bengal, India (Gupta *et al*.,2008),vegetables (25 mg/kg) from Turkey (Turkdogan *et al*., 2002) and vegetables grown on irrigated soil in Ilorin (4.8 mg/kg in Amaranthus and 1.5 mg /kg in Corchorus) reported by Ogunkunle *et al.*(2015). More so, this result is close to the finding of Sharma *etal*. (2006) who reported Cd level of 0.50-4.36 mg/kg in Vegetables from Varanasi, India (Turkdogan *et al*., 2002).

Copper concentrations in Amaranthus and Corchorus collected from studied peri-urban farms were below the permissible limits set by FAO/WHO and EU (2006). The mean concentration of Cu in vegetables (4.63 mg/kg for Amaranthus and 7.36 mg/kg for Corchorus) was lower than Cu content in vegetables (61.20 mg/kg) from Zhengzhou city, China (Liu *et al*.,2005) and also lower than the result (15.66-34.49 mg/kg) reported in Titagarh West Bengal, India (Gupta *et al.*, 2008).However the variation of Cu concentration in the present study was strongly supported by the findings of Arora *et al*. (2008) who reported Cu level of 5.21-18.2 mg/kg in vegetables and also in good agreement with Cu concentration in leafy vegetables (8.51-15.5 mg/kg) from Samanta village, Jessor, Bangladesh obtained by Alam *et al*. (2003). Higher Cu concentration was found in Corchorus.

The maximum concentration of lead was exhibited by Amaranthus (3.787 mg /kg). Lead concentrations in vegetables collected from studied peri-urban farms exceeded the permissible limits set by FAO/WHO and EU (2006).Lead content in vegetables was lower than the values reported in Titagarh, West Bengal, (21.59-57.63 mg/kg) and significantly lower than the mean concentration of Pb (409 mg/kg) reported in vegetables from Turkey by Turkdogan *et al.*(2002) but comparable with Pb level reported (0.18-7.75 mg/kg) in China (Liu *et al.,* 2005) and in Varanasi, India (3.09-15.74 mg/kg) bySharma *et al.,*2008b).

Vegetables collected from peri-urban farms exceeded the permissible limits set for Znby FAO/WHO and EU (2006) except in Amaranthus collected from farms 5 and 15 and Corchorus from farms 4,5, 8, 14 and 15.Highest mean concentration of Zn was found in Amaranthus (86.30 mg/kg) and Corchorus (43.43 mg/kg). Zinc concentration in vegetables from studied peri-urban farms was similar to vegetables (32.01-69.26 mg/kg) from Beijing, China (Liu *et al*., 2005) also from Rajasthan, India (21.1-46.4 mg/kg) reported by Arora *et al.*(2008) and vegetables of Varanasi (59.61-79.46 mg/kg) but substantially lower than Zn concentration in vegetables (1,038-1,872 mg/kg) from Harare, Zimbabwe (Thandi *et al*., 2004).

Vegetables studied were contaminated with heavy metals.Concentration ofheavy metals were higher in vegetables of peri-urban farms compared to the reference vegetable sample.Among the heavy metals studied in vegetables, Zn had the highest concentration followed by Cu, Pb and the least was Cd. Similar results were obtained by Abou Audu *et al.* (2011) who studied accumulation of metals (Fe, Zn, Pb and Cd) on crops in Gaza strip. Similar result was also obtained by Zhang *et al*. (2010) who reported that the maximum concentration was Zn, followed by Cu, Cr, Ni, Pb and Cd for two crops (*Cyperusmalaccensis* and *Scirpus triqueter*).Amaranthusshowed stronger ability to accumulate these metals from soil which is expected due to larger surface area of its leaves, higher transpiration and fast growing rate. This is consistent with the report of Oluwatosin *et al.* (2010). However, Corchorusaccumulated more Cu than Amaranthus which revealed potential use of Corchorus as a plant for environmental monitoring and soil remediation of Cu.

The pollution load index is aimed at providing a measure of the degree of the overall contamination of a sampling site. To effectively compare whether the peri-urban farms studied suffer contamination or not, the pollution load index was calculated. The peri-urban farms studied were moderately enriched with Zn and Cd but strongly enriched with Cu and Pb. There was substantial build-up of heavy metals in the soils of peri-urban farms compared to the reference soil. The high pollution load index of studied peri-urban farms suggested input from anthropogenic sources attributed to agricultural applications and irrigation practices.

Transfer factor is the ratio of heavy metal concentration in a plant to the concentration of heavy metal in the soil. It signifies the amount of heavy metals in the soil that ended up in the vegetable crop site (Chamberlain, 1983; Harrison and Chirgawi, 1989; Smith *et al.*, 1996). The soil-to-plant transfer factor is one of the key components of human exposure to metals through the food chain. In order to investigate the human health risk index, it is essential to assess the transfer factor (Ciu*et al*., 2005). When Transfer factor is < 1or = 1, it denotes that the plant only absorbs the heavy metal but does not accumulate and when TF >1, this indicates that plants accumulate the heavy metal.

Transfer factors were found to be higher for Cd and Zn whereas relatively lower values were found in Cu and Pb which varied with sampling site. The high transfer value of Cd and Zn indicate strong bioaccumulation of the metals by vegetables. Similar results were reported by Naser *et al*. (2011) where they found that Zn had the highest transfer factor among other metals and the order was Zn, Fe, Cd, Ni, Co and Pb and they also reported that the high mobility of Zn is a natural occurrence in the soil and the low retention of Zn in the soil than other toxic cations may elevate the Transfer factor of Zn. There existed strong correlation between Cd, Pb and Zn concentrations in the soil of peri-urban farms, Cd, Pb and Zn concentrations in Corchorus including Cu and Zn concentrations in Amaranthus and Corchoruswhich indicates similar sources of contamination. The general weak correlation between concentration of metals in soils and vegetables which has also been reported (Agbenin *et al*., 2009) indicates that other sources such as foliar absorption might have contributed to heavy metals burden in vegetables.The variations in heavy metal concentrations in vegetables were due to variations in their absorption and accumulation tendency. Soil properties such as pH, organic matter, redox potential, soil texture and clay may also affect heavy metal uptake (Overesch *et al*., 2007).

In this study, the only intake pathway considered forCd, Cu, Pb and Zn, was assumed to be vegetable consumption. The daily intake of metals values were estimated according to the average vegetable consumption for adults, and compared with the recommended daily intakes/allowance for metals (ATSDR, 1999a; FNB, 2001; Garcia-Rico *et al.*, 2007;USEPA, 2009).The results for the evaluation of DIM for Cd, Cu, Pb and Zn showed that the highest intake of Cd, Cu, Pb and Zn were from the consumption of Amaranthus. The estimated DIM of Cd, Cu, Pb and Zn were below the recommended daily intake/ allowance for metals. Zhuang *et al.* (2009) and Sharma *et al*. (2010) also found lower DIM values than tolerable daily intake limits. On the other hand, Sridhara *et al*. (2007) recorded higher DIM values for heavy metals than tolerable daily intake limits.

Cadmium in plant is highly mobile and it is likely to accumulate in both leaves and seeds. In this study, the transfer ratio of Cd between soil and vegetables was high. Strinivas *et al.*(2009) reported that vegetables had more Cadmium than animal products. According to FAO (1999) and USEPA (2009), the recommended daily allowance of Cd is 0.064 mg/day. In this study, vegetables grown in peri-urban farms were below the reported save limit. The DIM values for Cadmium ranged from 0.0003 to 0.001 mg/day and 0.0002-0.0016 mg/day for Amaranthusand Corchorusrespectively.Premarathna *et al.* (2011) reported Cd level ranging from 2.30 to 37.80 mg/kg in various vegetables. Okoronko *et al.,* (2006) reported values of between 22.59 mg/kg and 24.47 mg/kg in the vegetables under study. Naser *et al.* (2009)in Bangladesh reported higher level of Cd (53.69 mg/kg) which were more than values obtained in this study in vegetables. There are also evidences of uptake and accumulation in certain plants (ATSDR, 2005a). Cadmium is a toxic metal; it is classified as carcinogenic to human by international agency for research on cancer (IARC, 1993). Intake of too large quantities of Cd by humans from plant grown on Cd rich soils have higher chances of inducing the development of cancers of the lungs, nose, larynx and prostrate as well as inducing respiratory failures, birth defects and heart disorders (Duda-Chodak and Blaszczyk, 2008; Lenntech, 2009). Studies have shown that heavy metals such as Cd can stimulate cell growth in estrogen receptor (ER) positive breast cancer cells (Martin *et al.*,2003). Indeed, Ionescu *et al*. (2006) found highly significant Cd accumulation in 50 breast cancer tissue biopsies compared to control. In plants, Cd distribute the uptake and transportation of essential micro-nutrients (e.g Ca, Mg, P and K) and water (Nagajyoti *et al.*,2010).

Vegetables in this study had DIM lower than RDA(10 mg/ day) for Cu (USEPA, 2009). The DIM values for Cu ranged from 0.00021-0.016mg/day and 0.004-0.016 mg/day for Amaranthus and Corchorus respectively. Similar results have been reported by Uwah *et al*. (2011) who recorded Cu values of between 0.81 mg/kg and 1.75 mg/kg in Spinach and lettuce grown in Nigeria, respectively. Muhammad *et al*. (2008) and Akubugwo *et al*. (2012) also showed similar results in the ranges of 0.25 mg/kg to 0.92 mg/kg and 1.20 to 3.42 mg/kg of Cu respectively in vegetables studied.

Copper is required for the proper functioning of the neurovascular system. It is a component of several enzymes, co-factors and proteins in the body. In particular, Cu functions as an electron transfer intermediate in redox reactions as well as a direct role in maintaining cupro-enzyme activity. Changes in Cu status may have indirect effects on other enzyme status that do not contain Cu. The level of Cu in the body is affected by the level of Zn as it appears to exert an antagonistic effect on Cu status through the induction of metallothionein synthesis by Zn in mucosal cells in the intestine. Methalonine bound Cu is not available for transport into the circulation and is eventually lost in faeces (Gyorffy and Chan, 1992;Barone *et al.*,1998; Zahir *et al.*, 2009). Lower Cu uptake in human consumption can cause a number of symptoms which include growth retardation, Skin ailments and gastro-intestinal disorders. Copper deficiency impinges on Fe metabolism, causing anaemia that does not respond to Fe supplementation. Cu deficiency also exerts an effect on iodine metabolism resulting in hypothyroidism, at least in animal models (Michael *et al*., 2009).

Lead accumulation in many plants can exceed several hundred times the threshold of maximum level permissible for human (Wierzbicka, 1995). In this study, estimated DIM ranged from 0.002-0.014 mg/day and 0.0017-0.0076 mg/day for Amaranthus and Corchorus respectively. Naser *et al*. (2009), Orisakwe *et al*. (2012) and Akubugwo *et al*.(2012) reported Pb levels in the vegetables in ranges similar to those of this study. They reported values of between 0.35 to 3.89 mg/kg, 0.49 to 1.97 mg/kg and 0.13 to 0.73 mg/kg, respectively. Other studies showed that Pb metal level in spinach, coriander, lettuce, radish, cabbage and cauliflower were 2.251, 2.652, 2.411, 2.035, 1.921 and 1.331 mg//kg, respectively (Muhammad *et al*., 2008). According to the maximum allowable limit for Pb in vegetables which is 0.243mg/day, vegetables grown in peri-urban farms were lower than the limit.

Lead has no beneficial biological function and is known to accumulate in the body (Zurera-Cosano *et al*., 1984; Ellen *et al*., 1990; Yargholi and Azimi, 2008). Lead exposure can cause adverse health effects, especially in young children and pregnant women since Pb is a neurotoxin that permanently interrupts normal brain development. It also accumulates in the skeleton and its mobilization from bones during pregnancy and lactation causes exposure to fetuses and breastfed infants (WHO, 2004; ATSDR, 2007). Lead on a cellular and molecular level may enhance carcinogenic events involved in DNA damage, DNA repair and regulation of tumor suppressor and promoter genes (Silbegeld, 2003).

The daily metal intake of Zn was found to be below the recommended RDA of 60 and 40 mg/day by (FAO/WHO,1999) and USEPA (2009), respectively.In this study, the estimated DIM for Zn ranged from 0.053-0.259 mg/day and 0.023-0.144 mg/day for amaranthus and corchorus respectively. Result from this studywas higher compared with studies done by Akubugwo *et al.* (2012)on *Amaranthus hybridus*who reported values of Zn to be in the range of 1.06 to 2.88 mg/kg. Muhammad *et al*. (2008) also reported the amount of Zn in leafy vegetables samples as 0.461(spinach), 0.705 (coriander), 0.743 (lettuce), 1.893 (raddish) 0.777 (cabbage) and 0.678 (cauliflower) mg/kg, respectively.

Zinc is required by protein kinases to participate in signal transduction processes and is to be a stimulator of transducting factors responsible for regulating gene expression. Zinc plays an important role in the immune system and is an anti-oxidant *in vivo* (Demirenzen and Aksoy, 2006; Michael *et al*.,2009; Stranchan, 2010). Zinc deficiency can disturb Zn maintenance in human body. The clinical manifestations of Zn deficiency in human are growth retardation, neuropsychiatry disturbances, dermatitis, alopecia, diarrhea, increased susceptibility to infections and loss of appetite (Dermirezen and Aksoy, 2006; Michael, 2009). High concentration of Zn in vegetables may cause vomiting, renal damage, cramps e.t.c.

Inorder to assess the health risk of any chemical pollutant, it is essential to estimate the level of exposure by quantifying the routes of exposure of a pollutant to the target organisms. There are various possible exposure pathways of pollutant to humans but the food chain is one of the most important pathways.Vegetable consumption has been identified as one of the major pathways of human exposure to toxic heavy metals accumulated in vegetables. The health risk index for Cd, Cu, Pb and Zn from consumption of Amaranthus ranged from 0.30-1.20, 0.03-0.38, 0.10-4.75 and 0.18-0.86, respectively while it ranged from 0.20-0.90, 0.10-0.43, 0.35-1.68 and 0.08-0.48, respectively for consumption of Corchorus.The result showed high values for Cd and Pbbut low values forCu and Zn for both Amaranthus and Corchorus. Cadmium and Pbare non essential elements contributing to health hazards even at extremely low concentrations. Ikeda *et al.*(2000)and Zhuang *et al*. (2009) reported HRI values for Cd and Pb that are above permissible limits in vegetables and cereals. The values of Cd and Pb were high possibly because As, Cd and Pb were considered as the most significant heavy metals affecting vegetable crops (Anthony and Balwart, 2007).

Considering individualheavy metal, the health risk index is in the order Pb > Cd>Zn > Cu but when considering vegetables type, the health risk index was Amaranthus> Corchorus. The calculated HRIfor Cd and Pb from consumption of Amaranthus was greater than 1 in farms 1, 2, 3, 8 and farms 1, 2, 3,4, 8, 9, 10, 11, 12, respectively.Health risk index for Pb from consumption of Corchorus was greater than 1 in farms 1,2,8, 10, 11,12 and 13 which means that inhabitants around farms 1,2,3, and 8 are at significant risk of Cd toxicity from consumption of Amaranthus while inhabitants around farms 1,2,3, 4,8,9, 10,11,12, 13 are exposed to risk of Pb toxicity from consumption of either Amaranthus or Corchorus. The calculated hazard index for all the assayed heavy metals in Amaranthus and Corchorus of all the peri-urban farms studied was greater than 1. The findings of this study regarding HI suggest that vegetables grown in selected peri-urban farms are not safe for consumption.

This assessment was only to measure the intake of toxic heavy metals through vegetable consumption. Human beings are also exposed to heavy metals through other pathways such as consumption of contaminated food crops, eating of sick animals, milk etc (Wang *et al*., 2005; Khan *et al*., 2008; Sipter *et al*., 2008). Moreover, there may be other sources of metal exposures such as dust inhalation, dermal contact (Grasmuck and Scholz, 2005; Hellstrom, 2007) which were not included in this study.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

In this study, vegetables and soil samples collected from selected peri-urban farms around Osun State were analysed for their nitrate, As, Cd, Cu, Pb and Zn concentration. A control, set up in the greenhouse which served as the reference soil and vegetable samples were also subjected to similar treatment. Nitrate concentration in vegetables were within the published permissible level of nitrate in some vegetables and fruits. Investigated Heavy metals concentration in the soils of studied peri-urban farms were within the background range for farming set by FAO/WHO (2002) and EU (2006). The results obtained from vegetables analysis for Cd, Cu, Pb and Zn indicate appreciable levels of these metals in all the samples. Arsenic concentration was below detection limit in soils and vegetables collected from peri-urban farms. Variation in heavy metals concentration in soil and vegetables from peri-urban farms studied reflect the differences in farming practices.

Vegetables exhibited heavy metal concentration in higher ranges. Average metal concentration was higher in Amaranthus compared to Corchorus which suggest that Amaranthus has relatively higher bioaccumulation capacity compared to Corchorus and could be a good indicator of environmental pollution. However, Corchorus showed higher retention capacity for Cu revealing potential use of Corchorus as a plant for environmental monitoring and soil remediation of Cu.

The overall degree of pollution (PLI) indicates strong signs of pollution by the measured metals. Pollution load indexshowed substantial build-up of heavy metals in peri-urban farm soils compared to reference soil. There were indications that sources of these metals were mainly anthropogenic which may include traffic emissionsand agricultural input.

The potential health risk posed by vegetables contaminated with heavy metals was determined using the transfer factor (TF), extrapolation of daily intake of metals (DIM), health risk index (HRI) and hazard index (HI). The variability of heavy metals transfer factor was shown to be inherently strong for Cd and Zn but mild for Cu and Pb. Part of that variability could be explained by the effect of environment on biological functions responsible for the uptake, translocation and accumulation of heavy metals. This study also showed that vegetables under study may pose health risk to consumers as they were found to be deficient of essential metals such as Cu and Zn. on the other hand they were found to have higher than allowable level of metals such as Cd and Pb which are toxic metals. Also the hazard index of heavy metals in all the peri-urban farms studied was >1 indicating relative presence of health risks associated with ingestion of contaminated vegetables.

6.2 Recommendations

In order to decrease soil and plant contamination resulting from agricultural practices, the following are therefore recommended:

1. Regular monitoring of nitrate and heavy metals in soil and vegetables should be performed in order to prevent excessive build up in the food chain.
2. An intensive sampling is required for the quantification of the result throughout the country.
3. Government of Nigeria should task scientist to establish permissible limits for nitrate and heavy metals in soils and food crops.
4. Caution must be exercised in consumption of *Amaranthus hybridus* due to its ability to bio-accumulate heavy metals above the recommended safe limits which is a critical driver for high dietary exposure to metals consequently posing risk to human health.

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APPENDIX I

QUESTIONNAIRE

Personal Questionnaire for Assessing Peri-urban Farming Activities in Selected Areas

S/N	ITEMS	RESPONSE

1	How do you source for seeds?	
2	What is the source of water for irrigation?	
3	How do you maintain soil fertility?	
4	Is there anyagrochemical input?	
5	What are the vegetables grown on the farm?	
6	What is the age of vegetables at harvest?	
7	How productive is the system in terms of harvest?	

APPENDIX II

Table 1: Analysis of Variance for Comparison of Cd Concentration in Peri-urban Farm Soils and Reference Soil

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
FARM	15	0.796	0.053	9.58	<.0001

REP	2	0.032	0.016	2.86	0.073

Table 2: Analysis of Variance for Comparison ofCd Concentration in Peri-urban Farm Amaranthus and Reference Amaranthus

Source	DF	Sum Of Square	Mean Square	F Value	Pr > F
FARM	15	2.859	0.191	2.26	0.028
REP	2	0.163	0.082	0.97	0.392

Table 3: Analysis of Variance for Comparison of Cd Concentration in Peri-urban Farm Corchorus and Reference Corchorus

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
FARM	15	1.161	0.077	21.77	<.0001
REP	2	0.001	0.0006	0.18	0.838

Table 4: Analysis of Variance for Comparison ofCuConcentration in Peri-urban Farm Soils and Reference Soil

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
FARM	15	10964	730.9	37718	<.0001
REP	2	0.043	0.021	1.1	0.345

Table 5: Analysis of Variance for Comparison ofCu Concentration in Peri-urban Farm Amaranthus and Reference Amaranthus

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
FARM	15	257.4	17.16	579.9	<.0001
REP	2	0.019	0.009	0.32	0.729

Table 6: Analysis of Variance for Comparison ofCu Concentration in Peri-urban Farm Corchorus and Reference Corchorus

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
FARM	15	445.2	29.68	1158	<.0001
REP	2	0.041	0.02	0.79	0.462

Table 7: Analysis of Variance for Comparison ofPb Concentration in Peri-urban Farm Soil and Reference Soil

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
FARM	15	6439	429.3	152.7	<.0001
REP	2	1.095	0.547	0.19	0.824

Table 8: Analysis of Variance for Comparison ofPb Concentration in Peri-urban Farm Amaranthus and Reference Amaranthus

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
FARM	15	353.5	23.57	244.3	<.0001
REP	2	0.191	0.095	0.99	0.383

Table 9: Analysis of Variance for Comparison ofPb Concentration in Peri-urban Farm Corchorus and Reference Corchorus

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
FARM	15	79.84	5.323	111.1	<.0001
REP	2	0.109	0.054	1.14	0.335

Table 10: Analysis of Variance for Comparison ofZn Concentration in Peri-urban Farm Soil and Reference Soil

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
FARM	15	0.00003	23131	805.6	<.0001
REP	2	71.26	35.63	1.24	0.304

Table 11: Analysis of Variance for Comparison ofZn Concentration in Peri-urban Farm Amaranthus and Reference Amaranthus

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
FARM	15	48652	3243	369.2	<.0001
REP	2	21.47	10.74	1.22	0.309

Table 12: Analysis of Variance for Comparison ofZn Concentration in Peri-urban Farm Corchorus and Reference Corchorus

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
FARM	15	23449	1563	451.7	<.0001
REP	2	5.327	2.664	0.77	0.472

ABSTRACT

Keywords :

Supervisor:

xii, 135p

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Agriculture is often associated with rural areas, even though it has been practiced in urban and peri-urban areas since ancient times in backyards, on roof tops and road sides, in vacant plots and un-constructed areas, on river and lake beds and in other small land lots. Peri-urban agriculture refers to farm units close to towns which operate intensive semi- or fully-commercial farms to grow vegetables and other horticultural crops, raise chickens and other livestock, and produce milk and eggs (Stephanie *et al*., 2006). Peri-urban agriculture occurs within and surrounding the boundaries of cities throughout the world and includes products from crop and livestock agriculture, fisheries and forestry. The territory included within official city boundaries varies enormously across countries and can be more or less built-up, densely to sparsely populated. The distinction between "urban" and "peri-urban" depends on the density, types, and patterns of land use, which determine the constraints and opportunities for agriculture (Mukundi *et al*., 2014). What these diverse activities have in common and in some cases what sets them apart from rural agriculture is proximity to large settlements of people, thereby creating opportunities as well as risks.

Peri-urban agriculture reduces food insecurity by providing direct access to home-produced food to households and to the informal market (Van Leeuwen, 2001; Hillel, 2001). Much of peri-urban agriculture is for own consumption with occasional surpluses sold into the local market. Even for people who have little or no land, part-time farming of vegetables can provide food and income (Agbonlahor *et al.*, 2007). Peri-urban agriculture also enhances food security during times of crisis and severe scarcity (Nwauwa and Omonona, 2010) whether caused by national crises (civil war, widespread drought, currency devaluations, inability to import, etc.) or household crises (illness, health, sudden unemployment, etc.). Peri-urban farming plays an important role in providing emergency supplies of food (Akuffo and Irene, 2013), enhancing the freshness of perishable foods reaching urban consumers, thereby increasing overall variety and the nutritional value of food available. An important reason appears to be that food produced by consumers or in close proximity to them is often fresher than food that travels long distance to markets.

Peri-urban agriculture offers opportunities for productive employment in a sector with low barriers to entry. Over 800 million urban residents worldwide are estimated to be involved in food-producing activity (UNDP, 1996; FAO, 1999). Peri-urban agriculture is often carried out on a part-time basis by women, who can combine food production activity with child care and other household responsibilities. Peri-urban producers achieve real efficiencies by making productive use of under-utilized resources such as vacant land, treated wastewater and recycled waste, and unemployed labour (Abdulai, 2006). Productivity can be as much as 15 times the output per acre of rural agriculture; however, yields often suffer from inferior or insufficient inputs, use of poorly adapted varieties, poor water management, and lack of farming knowledge.

Horticultural production has expanded in and around cities in many developing countries as an informal activity practiced by poor and landless city dwellers. The broad diversity of horticultural crop species allows year-round production, employment and income (Akinmoladun and Adejumo, 2011). Growers have realized that intensive horticulture can be practiced on small plots, making efficient use of limited water and land resources. Horticultural species, as opposed to other food crops, have a considerable yield potential and can provide up to 50 kg of fresh produce per m^2 per year depending upon the technology applied. In addition, due to their short cycle they provide a quick response to emergency needs for food (several species can be harvested 60 to 90 days after planting.) Leafy vegetables provide a quick return to meet a family's daily cash requirements for purchasing food. Leafy vegetables are particularly perishable and post-harvest losses can be reduced significantly when production is located close to consumers.

Vegetable production is done mainly during the rainy season in Southwestern Nigeria. During this season, vegetables are easy to grow as water is available and farmers can avoid the cost of irrigation (Olasantan, 1996). Vegetable production is one of the most important enterprises of peri-urban production systems in Nigeria because vegetables are an important component of human diet and they can be easily cultivated on small areas (Ojo *et al*., 2011). Whereas, the Food and Agricultural Organization of the United Nations (FAO) and the World Health Organization (WHO) recommended a daily vegetable intake of 200 g per person, the Nigerian National average is below this value (Kintomo *et al*., 1997). This inadequate intake of fresh vegetables may further be worsened during the dry season when moisture scarcity limits the area under cultivation and quantity of vegetables that can be grown and supplied to the urban areas. On the other hand, a previous study by Kintomo *et al.* (1997) in Ibadan indicated that it was more profitable to grow vegetables during the dry season than in rainy season. Growing vegetables during this period also leads to higher quality produce because of low disease pressures and pest infestation compared to vegetables grown under rain-fed conditions. In that study however, 81% of farmers rated water management and/or poor drainage system as the most important abiotic constraint limiting dry season vegetable production.

The risks from agricultural production systems in peri-urban areas to health and environment can arise from the inappropriate or excessive use of agricultural inputs (especially pesticides, inorganic fertilizers, raw organic matter containing undesirable residues such as heavy metals) that may leach or runoff into drinking water sources; air pollution (e.g. carbon dioxide and methane from organic matter, ammonia, nitrous oxide and nitrogen oxide from nitrates); and odour nuisance (Khai *et al*., 2007; de Neergaard *et al.,* 2009). In particular, produce (especially leafy vegetables) can be contaminated by heavy metals through overuse of agrochemical sprays. Although none of these problems are specific to peri-urban production as they also result from inappropriate management in rural areas, the potential negative impact is greater in urban settings due to space limitation (Senouci *et al.*, 1993; Albrecht *et al*., 1995). Furthermore, while peri-urban agriculture consists of small production units that may not present problems individually, and thus are not subject to controls or environmental restrictions, they can create substantial problems through cumulative effects.

Peri-urban farming and the agronomic practices associated with it is a widespread activity around the world and there is a growing body of knowledge on peri-urban farms contaminated with heavy metals while the effects of heavy metals on human health are well documented (Liu *et al.,* 2005; Mapanda *et al.*, 2005; Rattan *et al*., 2005; Rothenberg *et al*., 2007; Ojo *et al.,* 2010; Khaled and Muhammed, 2016). Additional insights into metal uptake and accumulation in relation to the potential human health risks associated with peri-urban vegetable farming is still needed.

1.2 Statement of Research Problem

Farming within and around urban centres (peri-urban farming) is a major source of fresh crop produce, notably vegetables. However, the limitation of land resources and the associated high level of soil contamination from domestic and industrial pollutants are major concerns for the safety of food materials from peri-urban farming. Reported excessive accumulation of heavy metals by food crops from agricultural soils coupled with dearth of empirical data regarding heavy metals accumulation through peri-urban farming activities are major sources of concern, hence this study.

1.3 Objectives of Study

Objectives of this study were to:

f. identify sources of water used in peri-urban farms of selected areas in Osun State;

g. assess the appropriateness of agronomic practices in selected peri-urban farms;

h. investigate the soil chemical properties as well as pollution load of selected peri-urban farms;

i. assess uptake of selected metals by vegetables; and

j. assess the potential health risks associated with human consumption of peri-urban vegetables.

CHAPTER TWO

LITERATURE REVIEW

2.1 Peri-urban Farming

Peri-urban agricultural sector is an agricultural production system together with pre- and post-production support services within the immediate surroundings of cities (Mohammed and Folorunsho, 2015). Commercial peri-urban vegetable productions are usually located within peripheral zones near major urban conglomerates. These zones form a belt of varying radii with market-oriented intensive vegetable production often affected by, or causing, environmental hazards (Richter *et al.*, 1995). The volume and diversity of demand for food stimulated the need for increased agricultural production around vicinity of cities. The inability of rural farmers to cope with food demand of urban population generated interest in promoting the development of peri-urban practices. Economic needs and knowledge of peri-urban farming has transformed the left over land from urbanization into farms dominated by short cycle crops. The farms are developed to satisfy desire to generate household income, improve family nutrition, contribute to employment generation and poverty reduction.

World-wide, some 800 million persons are believed to be involved in some form of peri-urban agriculture (Smit *et al.*, 1996). It is often assumed that the profitability and sustainability of peri-urban agriculture in general, and that of vegetable production in particular, is virtually guaranteed by the nearby existence of large populations, relatively low transportation and packaging costs and low post-harvest losses. Enhanced peri-urban farm income would provide the base for investment in value-adding and other high return activities in peri-urban areas while contributing to overall economic growth (Goletti *et al*., 1999; Boncodin, 2000).

Urban population worldwide is growing at twice the rate of total population growth (World Bank, 2000), creating unprecedented demands for goods and services as well as increasing pressure on the environment. The importance, characteristics and potential of peri-urban agriculture in developing countries has received due recognition only recently. Vegetable commodities in particular have received increasing attention since they are highly perishable, and when cool chains are rare or incomplete as in much of the developing world, are often produced close to where they will be consumed. Hence, "Vegetable production has thus become concentrated in peri-urban zones where there exist large urban populations and high income elasticities of demand" (Jansen, 1992). Example from China demonstrates dramatic shifts in occupations and incomes of peri-urban communities (Jansen and Midmore, 1995). There are higher income and employment opportunities amongst peri-urban producers of vegetables than their rice-producing counterparts which have been sufficient to compete with urban demands for labour. Over a 15-year period, a complete shift of land use has taken place away from rice cultivation to a predominately vegetable production system and from an agricultural to a non-agricultural dominated work force. On average, financial returns for vegetable production were greater than for cereal production but also much more variable. Financial solvency of peri-urban farms is not only an issue to developing countries, but in developed countries too. Nugent (2000) argued that intensive peri-urban vegetable production can utilize an under-employed work force, but this is not so where less arduous and better paid employment is available in industry. Increasing costs for hired labour could result in production of some peri-urban vegetable crops becoming less competitive than those rurally grown (Rosegrant and Hazell, 2000).

The argument that peri-urban vegetable production systems can absorb significant quantities of city waste is supported by experiences from Vietnam and the Philippines (Jansen and Midmore, 1995), and to a lesser extent, Ghana and Burkina Faso (Dittoh *et al*., 2013). Peri-urban vegetable production systems offer potential solutions to municipal goverrnments faced with insurmountable issues of waste management and disposal. Jansen *et al*. (1996) estimated that peri-urban vegetable production could assimilate 665,000 tonnes of organic wastes per year. Average waste production per capita in low-income countries is consistently estimated at 150 kg /year (Medina, 1993; Simpson, 1993). In developing countries however, the use of 'true' composted urban wastes is scarce and instead, urban organic wastes are frequently used as a 'compost' input (a euphemism for city waste, including sewage) to peri-urban horticulture, which is also a source of waste (sewage) water for irrigation (Allison and Harris, 1996). Unlike chemical fertilizer, the use of various forms of urban waste has the potential to help prevent soil degradation and erosion by adding organic matter to the soil, and closes the mineral nutrient cycle (Midmore, 1995).

Most peri-urban agricultural operations in general and peri-urban vegetable production in particular, face rather poor prospects. There is pressure from various competing land uses within the urban environment. Another key concern of peri-urban agriculture is the risk of pathogen and heavy metal contamination to consumers due to the high dependency of production systems on the large amount of cheaply available organic wastes and waste water materials (Khai *et al*., 2007; de Neergaard *et al*., 2009) and lack of a clear policy regarding the practice and planned management of urban agriculture in most African cities (Ezedinma and Chukuezi, 1999; Olofin and Tanko, 2003; Wakuru and Drescher, 2008). In the long run unless promotive policies and improved technologies become available and farmers get compensated for the positive externalities generated by their production activities, negative externalities of peri-urban farming might be imposed on the society.

2.2 Water Use for Peri-urban Farming

Water is one of the most important inputs essential for crop production. It profoundly influences photosynthesis, respiration, absorption, translocation and utilization of mineral nutrient. The application of water and its managed uses has been an essential factor in raising productivity of agriculture and ensuring predictability in output (FAO, 2002). Sustainable water management helps to ensure better production both for direct consumption and commercial disposal.

The competition for freshwater resources between domestic demands, industry, commerce, institutions such as hospitals, and agriculture has increased as a result of increase in world population. Water demand has tripled since the 1950s (Brown, 2003). A huge increase in the number of wells and over-pumping with increasingly powerful diesel and electrical pumps is leading to falling water tables. Surface water from rivers is also tapped for freshwater and major rivers either completely dry up before reaching the sea or contain only a very small volume of water. About 70% of surface and groundwater is used for agriculture, however with increasing competition between agriculture, industry and domestic demand, agriculture is beginning to receive less water (Brown, 2003).

The use of waste water for agriculture in and around cities across the world is a current and future reality that cannot be denied. In some countries, such as Mexico and China, it has been practiced for centuries (Shuval *et al.,* 1986). Since conventional treatment is very costly, most waste water is allowed to be dumped, untreated, into water bodies or onto the land. The growing demand of water for irrigation has produced a marked increase in the reuse of treated and/or untreated waste water worldwide. The use of industrial or municipal waste water in agriculture is a common practice in many parts of the world (Blumenthal *et al*., 2000; Ensink *et al*., 2002; WHO, 2006; Sharma *et al*., 2007). Rough estimates indicate that at least twenty million hectares in 50 countries are irrigated with raw or partially treated waste water (Hussain *et al.*, 2001; Scott *et al*., 2004). The major objectives of waste water irrigation are that it provides a reliable source of water supply to farmers and has the beneficial aspects of adding valuable plant nutrients and organic matter to soil (Horswell *et al.*, 2003; Liu *et al*., 2005).

Untreated waste water use for peri-urban agriculture is often either ignored or actively condemned by the public and by government officials. A primary exposure route for urban population in general is the consumption of raw vegetable that have been irrigated with urban waste water (Scott *et al*., 2004). In many developing areas however, non-built up urban lands, especially those lying along the courses of urban drainage systems, are sometimes seen as locations for the production of some agricultural products that are in high demand by urban dwellers (such as vegetables). Several researchers have shown that a significant proportion of a city's food requirements in developing countries are supplied from within the urban boundaries, because within those areas, substantial amount of wastewater (mainly from homes and industries) is available in urban drains for irrigating lands along the urban drainage courses. Since the early 1990s, in particular, there has been increasing recognition amongst the scientific and development communities of the rising importance of waste water-based food production in city areas, particularly in those parts of the world that have been characterized by economic collapse (Mbiba and Van Veenhuizen, 2001).

Demand for water by peri-urban vegetable production compounds already existing competition from residential and industrial users for limited supplies in an environment where the marginal value product of water is high, heightening potential conflict (Abernethy, 1997). Increased construction in cities leads to reduced infiltration, increased runoff, less underground water storage and greater flooding risk. To some degree the retention of vegetable fields near cities, whether intentional or serendipitous (e.g. empty lots awaiting construction), offset these issues and certainly should be encouraged. An excellent example is the retention in Taiwan of the intensive horticultural region of Chang Hua county in an area of rapid industrial development.

Besides quantity, quality of metropolitan water as affected by industrialization, urbanization, sewage/effluent disposal and agricultural practices, has important impacts on vegetable quality and sanitation. Grey water can be used in power stations and for other industrial applications, treated effluent can be used in peri-urban agriculture, and potable water for domestic purposes. Taxing the use of water resources offers a potential solution to further regulate its allocation, as in the Netherlands where peri-urban farmers not only are liable to a tax on their use of groundwater resources but also subject to a compulsory registration system regarding the quantities of ground water used and drain water produced. A simpler system is in place in India: farmers irrigating with sewage water in the Hubli–Dharwad twin city pay a nominal annual charge to the twin city corporation, but this is not enforced (Nunan, 2000). Only with enforcement could water treatment and distribution be improved.

2.3 Input Use in Peri-urban Farming

2.3.1 Seed Source

Peri-urban farmers source for their seed locally or from produce. Farmers use the carryover seed stock from previous year for planting. Most peri-urban farmers obtain their seed for the next cropping season from the remnant of the field. Vegetables are rarely cultivated to produce seeds (Akoroda and Akintobi, 1983). The advantage of local seed multiplication is that cost of transportation and packaging that constitute bulk of the overall production cost is removed (Cromwell, 1994).

Non–availablity of improved seed is a major challenge to productivity of Peri-urban vegetable farming (Adeboye *et al.*, 2005). Okafor (1979) reported that 83.3% of farmers sampled in Nigeria identified lack of seed and planting materials as a major constraint to productivity. Most farmers extract their seed by crude methods which adversely affect seed quality and viability leading to seed deterioration and production of weak seedling. Also, plants are usually left in the field for too long thereby exposing seeds to disease and infection. When fruits are left on the plant for too long, some fully ripe inflorescence will shatter and shed their seeds resulting in wastage.

2.3.2 Inorganic Fertilizer

The use of inorganic fertilizers in vegetable production has in the past generated concern about the health effects, especially of nitrates in fresh leafy vegetables (Ngigib *et al.*, 2010). Application of nitrate fertilizers in vegetables by small holder is common both in developing and developed countries (Santamaria, 2006). Nitrates are safe. However, its metabolite nitrite is carcinogenic hence ingestion of nitrates may have long term health effect (Sanchez-Echaniz *et al.*, 2001).

Phosphate fertilizer are considered to be the major source of heavy metals input especially cadmium in pastoral soils in Australia and New Zealand and paddy soil in Asian countries. There have been greater efforts to reduce the accumulation of Cd in soils through the use of low Cd-containing phosphorus fertilizers. This is achieved by either selective use of phosphate rocks with low Cd or treating the phosphate rocks during processing to remove Cadmium. Superphosphate fertilizer manufacturers in many countries are introducing voluntary controls on the Cd content of phosphate fertilizers. For example, the fertilizer industry in New Zealand has achieved its objective of lowering Cadmium content in phosphate fertilizers from 340 mg Cd kg^{-1} P in the 1990s to 280 mg Cd kg^{-1} P by the year 2000. A number of phosphate rocks with low Cd are available which can be used in many countries for practical and economic reasons (Bolan *et al.,* 2003).

Several chemical processes to remove Cd from phosphoric acid before it is converted to phosphate fertilizers have been examined. These include extraction of wet phosphoric acids with amine and by ion exchange resins. For example, calcinations which refer to heating of phosphate rocks usually in the presence of silica and steam are aimed at reducing Cd content through its volatization. However, calcinations may not become a likely option in the fertilizer industry because it is expensive and calcinations decrease the reactivity of phosphate rocks, making them less suitable for direct application as a source of phosphate (Bolan *et al.*, 2003).

2.3.3 Organic Nutrient/Manure

In addition to inorganic fertilizers, different materials are also frequently used as sources of organic nutrient e.g animal manure of which poultry waste is the most sourced for. Poultry waste is an important soil ameliorating resource for vegetable production. Types and quality of poultry waste product hardly receive consideration when the waste is being sourced. Poultry waste is usually a combination of poultry bird faeces, urine, saw dust and remnants of animal feeds, drugs and pesticides. Conveyance cost is usually high due to its weight and bulkiness. There are no specific vehicles assigned or designed for poultry waste haulage, no standard measures for poultry waste collection and packaging although the informal nature of the poultry waste business plays a major role. Storage of poultry waste is mainly by heaping and covering. Poultry waste is buried in between farm ridges and covered with leaves. This mode of treatment is adopted due to lack of skill for proper composting methods, insufficient space, time and paucity of capital. Other reasons are the burdensomeness of the long processes required for its treatment and inadequate access to other needed materials such as ash. Application is manual and it is done without protective gadgets like boots and nose mask. Reasons for non use of protective gadgets relate more on non economic factors like ease and convenience of application. With these perceived benefits associated with poultry waste utilization, the challenges and uncertainty about its quality and suitability for food production has generated research interest particularly with some reported cases of poultry bird flu in parts of the world including Nigeria. Apart, larger number of empirical studies in African cities on the use of poultry waste for food production has focused more on the fertilizing value than on the health and environmental impacts (Kiango *et al*., 2001; Nsiah-Gyabaah *et al*., 2001).

Poultry waste addition is increasingly being recognized as a major source of metal input to soils, with repeated applications having resulted in elevated concentration of metals in soil.

For example, the annual metal inputs to agricultural land in England and Wales from animal manures amounted to 5247, 1821 and 225 mg/kg of Zn, Cu and Ni, respectively which represent 25-40% of the total inputs (Nicholson *et al.*, 1999). Similarly, Jinadasa *et al*. (1997) surveyed Cd levels in vegetables and soils of Sydney, Australia and concluded that the increase in Cd and Zn in vegetable soils were due to repeated applications of poultry manure.

Xiong *et al*. (2010) investigated the concentration of Cu in pig, cattle, chicken and sheep manure in China and showed that the mean Cu concentration in pig, cattle, chicken and sheep manure were 699.6, 31.81, 81.8 and 66.85 mg/kg, respectively. This can be a major input of Cu to agricultural land. Similarly, in New Zealand, land application of dairy pond effluent, based on Nitrogen loading of 150 kg N ha^{-1}, is likely to add maximum of 31.5 kg Cu ha^{-1} and 73.7 kg Cu ha^{-1} through effluent and manure sludge application, respectively (Bolan *et al*., 2003). Martinez and Peu (2000) estimated that 183 kg Cu and 266 kg Zn, respectively, were added to soil through 8 years of swine manure application, most of which accumulated in the surface soil.

Metals in manure by-products are also derived from ingestion of contaminated soil by animals and also during manure collection and handling, a number of metals are added to livestock and poultry feedstuff not only as essential nutrients but also as supplements to improve health and feed efficiency. In confined intensive animal production systems, a number of feed additives are used to improve feed efficiency and to reduce out-breaks of diseases (Papaioannou *et al*., 2005). Among the many feed additives, the metal(loid)s As, Co, Cu, Fe, Mn, Se, and Zn are added to prevent diseases, improve weight gains and feed conversion, and increase egg production in the case of poultry (Mondal *et al*., 2007). Similarly, regular use of growth promoters containing metals is likely to result in elevated concentrations of these metals in excreted faeces and urine, concentration in manure by-products depend primarily on their concentrations in the diet (Mondal *et al*., 2007). For example, Kunle *et al*. (1981) and Sutton *et al*. (1983) observed that Cu concentration in swine and poultry manure by-products were linearly related to Cu added in the diet. Similarly, Mohanna and Nys (1999) noticed that by reducing dietary Zn from 190 mg/kg to 65 mg/kg in broiler poultry feed resulted in a decrease of Zn concentration in manure by 75%. Introducing highly viscous raw materials such as triticale, rye and barley at high levels in poultry diets has been shown to reduce Zn retention, thereby contributing to increase level of Zn in manure (Mohanna and Nys, 1999). Mondal *et al*. (2007) obtained a significant correlation ($R^2 = 0.89$, $p < 0.05$) between Cu in swine feed and faeces Cu concentration. The concentration of Cu in feed samples ranged between 6.86 mg/kg and 395.19 mg/kg and Cu concentration in pig faeces were approximately 5-times greater than in pig feed.

As in the case of animal diet, the majority of metals used in animal health remedies also eventually reach the end-use by-product. Addition of As to feed as an additive to control coccidiosis in poultry has been shown to result in seven fold increase in As level in poultry litter (Mohanna and Nys, 1999). Similarly the excessive use of Cu compounds as growth promoter in swine and poultry, and as a footbath in milking yards to treat lameness in dairy cattle can result in elevated concentration of Cu in effluents and manure products (Bolan *et al*., 2003).

Christen (2001) obtained a direct correlation between water extractable As in soils and the amount of poultry litter applied, implicating this materials as a major source of As input in soils. The organic As compounds have been used as feed additives for swine disease control and weight improvement in China. Li and Chen (2005) investigated As concentration in pig feeds and manure ranged from 0.15 to 37.8 mg/kg and 0.42 to 119.0 mg/kg, respectively. They reported that the potential soil As increase rates resulting from land application of pig manure might range between 11.8 g kg^{-1} $year^{-1}$ based on the loading rates of pig manure of 2.7-57.2 t ha^{-1} $year^{-1}$.

Soil ingestion has been identified as an important source of Cd ingestion by grazing sheep and cattle in New Zealand and Australia (Mondal *et al*., 2007). For example, it has been estimated that in New Zealand, sheep ingest 11-30 g soil per day soil in the summer and 264-275 g soil per day during the winter. The corresponding values for cattle are 220-470 g soil per day in summer and 900-1600 g soil per day in winter (Mondal *et al.*, 2007). Based on these values and the average Cd concentration of 0.1-0.5 mg/kg in pasture soils, it can be estimated that approximately 15 mg and 90 mg of Cd is ingested annually through soil by sheep and cattle, respectively most of which is excreted in the manure.

2.3.3 Agrochemical Products

Agricultural use of pesticides and herbicides is another source of heavy metals in arable soils from non-point source contamination. Although pesticides and herbicides containing Cd, Hg, and Pb have been prohibited in 2002, there are still other trace elements containing pesticides and herbicides in existence, especially Cu and Zn. It was estimated that a total input of 5,000 tons of Cu and 1,200 tons of Zn were applied as agrochemical products to agricultural land in China annually (Luo *et al.*, 2009). Cocoa, groundnut, mustard and rice in China had elevated concentrations of heavy metals (especially Cu and Zn) assessed when compared to other plants (cabbage, oil palm, and lady's fingers). This may be contributed by the widespread use of Cu and Zn pesticides on these crops.

2.4 Environmental Impacts of Peri-urban Farming

Over recent decades, peri-urban agriculture has made tremendous adjustment to meet the growing demand for inexpensive and safe supply of vegetables during the dry season and this growth has been accompanied by the emergence of “land-dependent” farming establishment. All setbacks along major highways are used for peri-urban farming. As a consequence, contaminated soils are unwittingly put into cultivation. Due to the fact that industries are mainly located in peri-urban areas, often in close existence with agriculture (Navano-Avino *et al*., 2007), has caused a serious contamination of agricultural soils with heavy metals and turn them into a long term sink (Kabata-Pendias, 2011).

The extra-ordinary performance of peri-urban farming over the past three decades have been partially achieved through soaring use of inorganic and organic fertilizers as soil amendment. The intensification in the use of fertilizers resulted in expansion of cropland at the expense of forested land (deforestation), pollution in arable soil through intensive use of mineral fertilizer, herbicides, pesticides to maintain high crop yield also contributed to air pollution. Nitrous oxide produced from N fertilizer is a major air pollutant. FAO-IFA (2001) reported a 1 % N_2O-N (nitrogen in nitrous oxide). Green house gases emission got increased most importantly from deforestation.

Pollution of soil and water with heavy metals and pathogens is also a result of poor-manure management. Excessive use of agricultural input such as pesticides, inorganic fertilizer, raw organic matter may run off into water sources contaminating aquatic life. Water pollution from surface run off has been reported in literature with subsequent effects on nutrient enrichment, water quality impairment, marine life spawning, ground destruction and fish kill (Ogunfowokan *et al.,* 2005; Taiwo, 2010). Asimi (1998) also noted that effluents from farms increased water COD, total water hardness, turbidity among other water quality variables. Over exploitation of water resources during the dry season could result in draining of wetlands and reduction in biodiversity.

Local disturbance and landscape degradation are typical local negative amenities of peri-urban farming. Diversion of water ways and re-channeling for irrigation is a significant environmental issue resulting from peri-urban agriculture. Sometimes farming practices are done on flood plains, river banks, steep slopes and water side contributing to flooding and erosion. Substantial amount of waste water is used for irrigation in peri-urban farming. Talukder *et al.* (1998) reported that poor quality irrigation water reduces soil productivity, changes soil physical and chemical properties, create crop toxicity and ultimately reduces yield.

2.5 Heavy Metals Contamination in Peri-urban Farming

A valid definition for the term “heavy metals” has never been established (Duffs, 2002) nor has the term “trace metals”, which is often used synonymously, ever been defined exactly (Kabata-Pendias, 2011). Several sources defined heavy metals as elements with a density greater than 5 g /cm^3 (Morris, 1992). Heavy metals are environmental contaminant of great concern because due to their biochemical properties, they accumulate in environmental media (Kabata-Pendias, 2011). With respect to their toxicity, heavy metals can be divided into two groups: micronutrients like Fe, Mn, Mo, Cu, Ni and Zn and are essential in small amounts and the only toxic ones As, Cd, Hg, and Pb without any known biological function. The latter ones have higher impact on organisms, but even the essential heavy metals can become toxic if a specific concentration level is exceeded (Alloway, 1999).

Exposure to heavy metals continues to be an important issue today particularly in developing countries (Adriano, 2001; Jarup, 2003). Even in developed countries it was only towards the end of the 20th century that emissions of heavy metals declined, where for example in the UK between 1990 and 2000 emissions fell by over 50% (Jarup, 2003). Natural sources of metals can even be a problem, such as in Bangladesh where high concentration of naturally occurring arsenic have been found in the main source of potable water sources across more than 50% of the districts (Adriano, 2001).

Elevated heavy metal soil concentration may come from either geogenic or anthropogenic sources. While metals of geogenic origin are those which occur naturally in the parent materials, anthropogenic metals are deposited in the soil due to human activity. Typically metals arising from anthropogenic sources are more bioavailable than the naturally occurring forms and consequently pose greater risks of adverse human health effect.

Contamination of soils with heavy metals from anthropogenic activities is widespread and represent a serious problem for scientist and government throughout the world. The process and pathways by which contamination occur are varied including combustion followed by atmospheric deposition, run-off into surface waters from chemical spills storage and transport and direct application of products containing heavy metals to soils (Jarup, 2003). The United State Environmental Protection Agency (USEPA) has 13 metals on their priority pollutants list including Ag, As, Be, Cd, Cr, Cu, Hg, Ni, Pb, Sb, Se, Ti, and Zn. Each of these metals presents a unique problem for soil scientists researching contamination problem.

Wastewater irrigation, solid waste disposal, sludge applications, vehicular exhaust and industrial activities are the major sources of soil contamination with heavy metals, and an increased metal uptake by food crops grown on such contaminated soils is often observed. In general, wastewater contains substantial amounts of beneficial nutrients but also toxic heavy metals, which are creating opportunities and problems for agricultural production, respectively (Singh *et al*., 2004; Chen *et al*., 2005). "Excessive accumulation of heavy metals in agricultural soils through waste water irrigation, may not only result in soil contamination, but also lead to elevated heavy metal uptake by crops, and thus affect food quality and safety" (Muchuweti *et al*., 2006).

Heavy metal accumulation in soils and plants is of increasing concern because of the potential human health risks. This food chain contamination is one of the important pathways for the entry of these toxic pollutants into the human body. Heavy metal accumulation in plants depends upon plant species, and the efficiency of different plants in absorbing metals is evaluated by either plant uptake or soil-to plant transfer factors of the metals (Rattan *et al.*, 2005). Uptake of metals by plants may be a good indicator of efficiency of metal absorption of different crop species grown on soils having uniform metal level under controlled conditions. Whereas transfer factor of metal from soil to plants indicate the efficiency of crop species better where crops are grown on soils having variable metal content.

Heavy metals which are persistent environmental contaminants may be deposited on the surfaces and then absorbed into the tissues of vegetables. Plants take up heavy metals by absorbing them from deposits on the parts of the plants exposed to the air from polluted environments as well as from contaminated soils (Khairiah *et al*., 2004; Jassir *et al.*, 2005; Kachenko and Singh, 2006; Singh and Kumar, 2006; Sharma *et al*., 2008a,b). A number of studies have shown heavy metals as important contaminants of the vegetables (Singh *et al.*, 2004; Marshall, 2004; Sinha *et al.*, 2006; Singh and Kumar, 2006; Sharma *et al*., 2006, 2007, 2008a,b). Heavy metal contamination of vegetables may also occur due to irrigation with contaminated water (Singh *et al*., 2004; Sharma *et al*., 2006, 2007; Singh and Kumar, 2006). Emissions of heavy metals from the industries and vehicles may be deposited on the vegetable surfaces during their production, transport and marketing. Jassir *et al*. (2005) reported elevated levels of heavy metals in vegetables sold in the markets at Riyadh city in Saudi Arabia due to atmospheric deposition. Recently, Sharma *et al*. (2008a,b) reported that atmospheric deposition can significantly elevate the levels of heavy metals contamination in vegetables commonly sold in the markets of Varanasi, India

2.6 Soil-plant-man Interaction for Heavy Metals

According to Kosvacs (1992), plants, most especially ruderals, have the ability to bio-accumulate metals in high quantities without visible injury. Heavy metal absorption by plants is governed by soil characteristics such as pH and organic matter content (Jones, 1991; Sinlatan and Tuba; 1992). It has been reported that individual plant species greatly differ in their uptake of heavy metals.

The speciation and levels of the metal in the soil solution, the movement of the metal from the bulk soil to the root surface, the inward movement of the metal from the root surface, and the translocation of the metal from the root to the shoot come into play in determining the amount of metals absorbed by a plant (Wild, 1988). Plants do vary in their absorptive mechanism for different ions, but ions which are absorbed into the root by the same mechanism are likely to experience competition. For example, Zn absorption is inhibited by Cu and H^+ but not by Fe and Mn while Cu absorption is inhibited by Zn, NH_4^+, Ca and K (Graham, 1981; Barber 1984). The uptake of heavy metals by plants is determined by the increasing level of soil contamination (Alloway and Davies, 1971; Gracia *et al*., 1979; Grant and Dobbs, 1997).

Foliar absorption of solute is essential at meeting food need of mankind. Lingle and Holmberg (1975) used foliar sprays of Zn to correct deficiency of Zn in plants. Also demonstrated was the uptake of Zn from foliar sprays in bean plants by Bukavoc and Wittwer (1957). Tjell *et al*. (1979) reported foliar absorption to be significant route for the entry of atmospheric pollutants such as Cd into the food chain. Lead may remain largely as a superficial deposit on the leaves whereas Zn and Cd exhibited at least partial penetration into the leaves (Little and Martins, 1972).

Foliar absorption has a role to play in heavy metals uptake. Roots of plants are responsible for absorption of water and mineral elements but absorption of elements also takes place through the leaves. Also, foliar route has been reported to be of equal importance to the soil-root pathway (Alfaeni *et al.*, 1996). The primary source of heavy metals in the aerial parts of plant is generally said to be via aerial deposition (Bilegaard and Johnson, 1984; Chamel, 1986; Marschner, 1986; Bache *et al*., 1991; Zhang *et al*., 1995). Direct uptake of heavy metals through the leaf after deposition is an important route especially for lead (Breckle and Khale, 1992). The deposited particles may be washed by rain into the soil, re-suspended or retained on leaves (Harrison and Chirgawi, 1989). The degree of retention of metal is influenced by weather conditions, nature of pollutants, plant surface characteristics and particle size (Harrison *et al*., 1989). Great variation in heavy metal concentration in plants had been reported to depend on species and metal type (Agrawal *et al.,*1988; Jones, 1991; Snatalan and Tuba, 1992).

A number of factors contribute to the foliar absorption of solutes. These include plant species, nutritional status, age of the leaf, thickness of cuticle, presence of stomata guard cells, humidity of the leaf surface and the nature of solutes (Chamel, 1986; Marschner, 1986). Also reported was that particles deposition on leaf surfaces is affected by some factors, including particle size and mass, wind velocity, leaf orientation, sizes, moisture level and surface characteristics (Bache *et al*., 1991).

Soil-to-plant transfer is one of the key components of human exposure to metals through the food chain. Lacatusu *et al*. (1996) studied soil-plant-man relationship in heavy metals polluted areas in Romania and detected significant levels of Cd and Pb from the geogenic abundance viewpoint. Although the polluted soils were neutral to slightly alkaline and well supplied with organic matter, the soluble forms of heavy metals in EDTA-CH_3COONH_4, pH =7.0 represented on average 37% Cd, 17% Cu, 28% Pb and 14% Zn, respectively of their global concentration, exceeding the maximum allowable limit (MAL), for soluble forms, by on average up to 14.8 (Pb), 4.2 (Cd), 2.1 (Zn) times. The relationship between their contents in plants and in soil (soluble forms) showed significant correlations for Cd, Cu, Pb and Zn. As a result, the contents of these elements in vegetables often exceed those allowable for normal human and animal consumption.

In this case, if an adult consumed 2 kg potatoes, 2 kg tomatoes and 1 kg carrots in a week, his or her food would exceed by 12% the MAL for Cd (0.525 mg). The daily maximum allowable rate of ingested Pb (0.430 mg) could be reached by consuming 880 g of vegetables (equal parts of potatoes, tomatoes, carrots and cucumbers). Acidity of soils enhances the transfer of large amounts of heavy metals in soluble forms, exceeding MAL on average up to 23.4 (Pb), 2.1 (Cd), 2.8 (Cu) and 2.7 (Zn) times. As a result, the average Pb content in carrots was 10 times higher than the MAL and the Pb accumulation in the lettuce, Parsely and garden orach, significantly above the critical contents. At the same time, the Cd content in the analysed vegetable exceeded by 5 times the MAL, while the Cu and Zn contents were close to critical levels (Lacatusu *et al.*,1996). Ingestion of vegetables containing high concentration of heavy metals is one of the main ways in which these elements enter the human body.

Estimates from various countries showed the dietary intake for Pb in adults is between 54 mg per day (Arora *et al.*, 2008) and 412 mg per day (Lacatusu *et al*. 1996) and that of Cd is between 10 and 30 mg per day (Arora *et al*., 2008). For Zn and Cu, the estimated daily intake is from 1 to 3 mg, and 10 to 20 mg respectively (Arora *et al*., 2008). Lacatusa *et al*. (1996) found that their estimation for Pb and Zn in adults were above those reported from other countries whereas the estimation for Cd was within the range. The levels of Cu were observed to be below the estimation.

Bahemuka and Mubofu (1999) suggested that a large daily intake of these vegetables is likely to cause a detrimental health hazards to the consumers. Since the dietary intake of food may constitute a major source of long-term low-level body accumulation of heavy metals, the detrimental impact becomes apparent only after several years of exposure. Regular monitoring of these metals from effluents, sewage, manure, in vegetable and in other food materials is essential for preventing excessive build-up of the metals in the food chain (Bahemuka and Mubofu, 1999).

2.7 Peri-urban Vegetable and Human Health

Vegetables cultivated in waste water-irrigated soils take up heavy metals in large enough quantities to cause potential health risks to the consumers. In order to assess the health risks, it is necessary to identify the potential of a source to introduce risk agents into the environment, estimate the amount of risk agents that come into contact with the human-environment boundaries, and quantify the health consequence of the exposure (Ma *et al.*, 2006). Heavy metal contamination of vegetables cannot be underestimated as these foodstuffs are important components of human diet. Vegetables are rich sources of vitamins, minerals, and fibres, and also have beneficial antioxidative effects. In view of their generally high vitamin and micro-nutrient content, vegetables are commonly valued as an essential component of the human diet (Ali and Tsou, 1997) and peri-urban vegetable production contributes substantially to the sum total consumed within cities (e.g. 75% of annual consumption in Ho Chin Min City (Jansen *et al.,* 1996) and 80% in Hanoi (Tran, 2000). Although largely unquantified, peri-urban vegetable production contributes to the aesthetic properties of the urban–rural divide (FAO, 1999). Wang (1997) noted the shift in population away from city centres to peri-urban zones, presumably for an improved lifestyle. Smardon (1988) discussed the impact of green vegetation on general human health and wellbeing.

Intake of heavy metal-contaminated vegetables may pose a risk to the human health. Heavy metal contamination of food items is one of the most important aspects of food quality assurance (Marshall, 2004; Wang *et al.*, 2005; Radwan and Salama, 2006; Khan *et al*., 2008). International and national regulations on food quality have lowered the maximum permissible levels of toxic metals in food items due to an increased awareness of the risk these metals pose to food chain contamination (Radwan and Salama, 2006).

Peri-urban vegetables may exert a negative impact on the health of the urban populace via induced infections/toxicities attributed to the consumption of contaminated vegetables, even though the risks of human infection do not seem to be more serious than through consumption of vegetables produced in rural areas (Senouci *et al*., 1993; Albrecht *et al*., 1995). Although health risks from the use of organic urban wastes in peri-urban agriculture are often considered minimal (Furedy, 1996), human toxicity due to high concentration of heavy metals sometimes can occur in produce from peri-urban sources, e.g. in Hanoi (Tran, 2000). In addition, where peri-urban farmers in Hanoi use fresh human manure in peri-urban vegetable farming, virtually all children suffer from helminthiasis (Dang, 2000). In Burkina Faso, Ouedraogo *et al*. (2017) also reported that prevalence of gastroenteritis is usually higher in dry season among children compared to wet season. Finally, as in Ho Cin Minh City (Jansen *et al*., 1996) and Bangkok (Waibel and Schmidt, 2000), the widespread overuse of both inorganic fertilizers and pesticides by peri-urban vegetable growers is a potential danger to environmental health.

Prolonged consumption of unsafe concentrations of heavy metals through foodstuffs may lead to the chronic accumulation of heavy metals in the kidney and liver of humans causing disruption of numerous biochemical processes, leading to cardiovascular, nervous, kidney and bone diseases (WHO, 1992; Jarup, 2003). When ingested in trace quantities, some heavy metals such as Cu, Zn, Mn, Co and Mo act as micronutrients for the growth of animals and human beings whereas others such as Cd, As, and Cr act as carcinogens (Feig *et al.*, 1994; Trichopoulos, 1997), and Hg and Pb are associated with the development of abnormalities in children (Gibbes and Chen, 1989; Pitot and Dragan, 1996). Hartwig (1998) and Saplakog¢lu and Iscan (1997) have reported that long-term intake of Cd caused renal, prostate and ovarian cancers in human.

Fortunately however, the degree of microbial contamination is amenable to both production and post-harvest management. Judicious management and use of sewage effluent can reduce exposure to coliform bacteria, e.g. by covering the soil with plastic sheeting (Sadovski *et al*., 1978). Rinsing of contaminated vegetables causes measurable differences in bacterial counts and a chlorine wash solution reduced coliform population on broccoli by one log unit (Rosas *et al*., 1984). Objective inoculation with selected lactic acid bacteria (*Lactobacillus casei* strains) is effective in reducing or eliminating populations of coliforms and enterococci after the third day of refrigerated storage (Vescovo *et al*., 1995).

From a policy point of view, WHO guidelines exist for the safe use of wastewater and excreta in agriculture (Mara and Cairncross, 1989) and for acceptable concentrations of various organic and inorganic compounds in soils treated with reclaimed water and sewage sludge (e.g. Chang *et al*., 1995). Given the current and likely increase in use of sewage and effluent for peri-urban vegetable production, attention to the possible impacts of heavy metals on the safety of vegetable consumption is appropriate even though the evidence regarding their potential harm is mixed. No significant difference in heavy metal content was observed in a comparison between vegetable plants irrigated with well water or treated municipal waste water (Burau *et al.*, 1987), and preliminary evidence from West Africa (Bamako in Mali and Ougadougou in Burkina Faso) suggests that heavy metals, even though present in organic waste material, are not currently an issue of immediate concern. On the other hand, one study has found positive correlations between plant lead (Pb) concentrations in lettuce and the lead concentration in the sludge to lower the concentration of Pb (Sterrett *et al*., 1996). The concern with lead appears to be confined to production in urban areas: lead was found in high concentrations in urban soils at twice the values of rural or forest soils of Hong Kong, and studies of urban soils in Baltimore

(USA) also showed high average lead concentrations (Sterrett *et al*., 1996), attributable to automotive Pb emissions, aerosol emissions and Pb-based paints. The major current concern with Pb is the surface deposition of Pb-enriched dust on vegetables that will then be ingested, as is so in the highly urbanised Hong Kong area (Chan *et al*., 1989). As might be expected, distancing vegetable production from streets minimizes atmospheric deposition of Pb particles (Smit *et al*., 1996). Approximately 50% of surface deposited Pb is removed by surface washing.

Finally, there is the issue of nitrate content in the edible part of vegetables. Vegetables (particularly the leafy types) that are harvested during their major growth stage are still actively accumulating nitrogen and tend to have high nitrate concentrations. However, the overall effect on nitrate concentration is similar in vegetables harvested from peri-urban and rural sources (Cerutti *et al*., 1996; Yin *et al*., 1993), and this, together with the reported levels of heavy metals in peri-urban-produced vegetables (with exceptions for lead in urban situations) should give cause for serious concern amongst consumers of peri-urban vegetables (FAO, 1999b)

CHAPTER THREE

MATERIALS AND METHODS

3.1 Location of the Study Area

The study areas are geographically located in Osun State, Southwestern part of Nigeria. The State is situated in the tropical rain forest zone. It covers an area of approximately 14,875 sq km and lies between latitude 7° 30′ N and longitude 4° 30′ E. Though a landlocked state, it is blessed with presence of many rivers and streams which serve the water needs of the state. Osun has a fairly large population. According to the 2006 National Population Census, the population of the state is put at 3,423,535 inhabitants (NPC, 2006). The mean annual rainfall is 1,330 mm, though there are great deviations from this mean from year to year. The area is characterized with two prominent seasons which are the rainy and dry seasons. The rainy season lasts from mid-March to late October and rainfall is bimodal with peak periods in July and September. The dry season lasts from November to March. Annual temperature ranges from 27^0C to 34^0C with the highest range being experienced in the dry season. The study area constitutes a part of the Basement complex of Southwestern Nigeria and it is characteristically layered by hard igneous and metamorphic rocks (Symth and Mongomery, 1962).

Being an agrarian state, agriculture is largely practiced both at commercial and subsistence scales and this attracts people from outside the State. Major crops grown are cassava, maize, beans, yam, fruits and vegetables. Cash crops such as cotton, cacao and oil palm serve the local cottage industries such as cotton weaving, cotton seed milling, cocoa and palm oil processing.

The map of the study area is presented in Fig. 3.1. Many of the people in the State are involved in peri-urban farming. For the purpose of convenience and greater coverage,

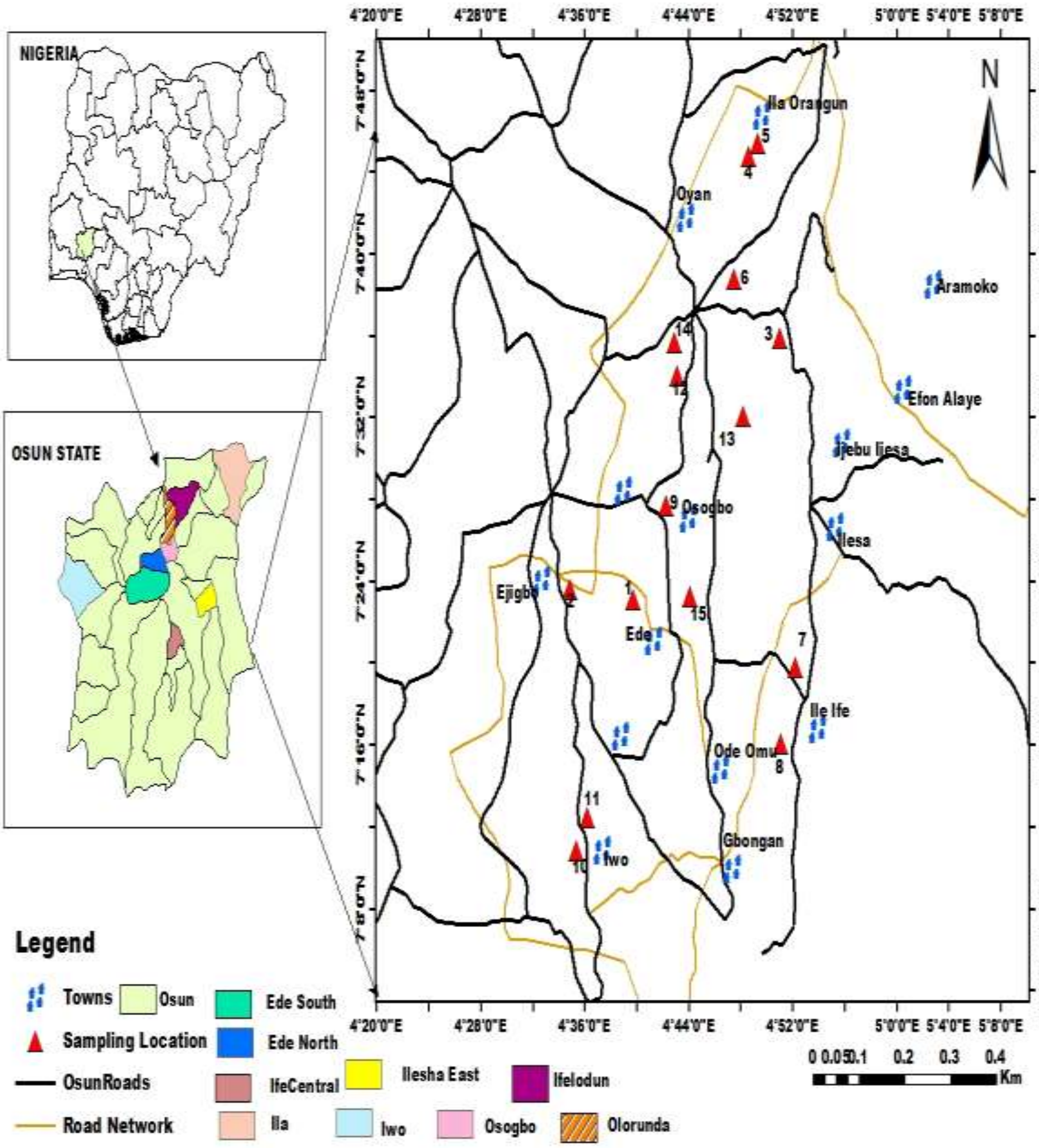

Fig 3.1: Map of Osun State Showing the Sampling Locations

sampling was carried out in seven cities namely; Ede, Ilesa, Ile-Ife, Ila-Orangun, Ikirun, Iwo and Osogbo. These locations were chosen because they represent the typical peri-urban dry season vegetable production system in Osun State. Osun State was specifically selected for this study because it is one of the most urbanized states in Nigeria.

3.2 Sampling Techniques

Sampling was carried out in each of the cities from January to April. Soil and vegetable samples were collected during the dry season from at least two farm locations per town. Soil and edible vegetable samples from selected peri-urban farms were collected twice, during the first and second planting cycles. A total of 15 farmers were interviewed in all the locations. The study was undertaken by face-to-face interview and personal questionnaire/ assessment of the farms. Some of the questions addressed by the questionnaire include general description of farming practices, sources of input, management and productivity.

3.3 Soil Sampling, Collection and Characterization

Soil samples were collected from each peri-urban farm. At each farm, soil samples were randomly collected from the upper horizon (0 -10 cm) using a soil auger and bulked together to form a composite sample. Each sample was immediately placed in a labelled black polythene bag, tightly sealed and sent to the laboratory. In the laboratory, soils were air-dried, crushed and sieved through a < 2 mm mesh, and then sealed in Kraft paper envelopes until analysis. Sub-samples were used to determine the desired chemical properties. The soil pH was determined by the method of Blakemore *et al.* (1987). Percentage nitrogen was determined using Kjeldahl digestion procedure (Nelson and Sommer, 1982). Organic carbon was also determined using the chromic acid determination method (Walkley and Black, 1934).

3.4 Plant Sampling, Collection and Preparation

Whole plant samples were collected by uprooting them from the same site where soils were collected using soil auger. Two vegetable species *Amaranthus hybridus* (Amaranth) and *Corchorus olitorious* (Jute mallow) were selected for health risk assessment because they are the most widely cultivated and consumed leafy vegetables in Southwestern part of Nigeria. Vegetables sampled were between 2-3 months at harvest. After harvesting, plant samples were separated into shoot and root. The shoots were packed into brown envelope and labelled accordingly for laboratory preparation while the roots were discarded. In the laboratory, vegetable shoots were properly washed with deionized water to remove all visible soil particles, weighed and then oven dried at 80^{o}C to constant weight. The oven dried samples were pulverized into fine powder using a stainless steel blender and passed through a 2 mm sieve. The resulting fine powder was stored appropriately, kept at room temperature before analysis and later digested and analyzed for nitrate, As, Cd, Cu, Pb and Zn concentrations.

3.5 Control/Reference Samples

A control was set up in the greenhouse of the Faculty of Agriculture, Obafemi Awolowo University, Ile-Ife which served as reference soil and vegetable samples. Soil samples and vegetable seeds sowed were provided respectively by the Departments of Soil Science and Land Resource Management and Crop Production and Protection in the Faculty of Agriculture. Vegetable seeds were sown in soil spread out in perforated bowls irrigated with unpolluted water and without the application of fertilizers, manures, herbicides and pesticides. Collections of samples were made twice from January to April at about the same time sampling was being carried out in peri-urban farms.

3.6 Chemical Parameters of Soil

3.6.1 pH Determination

The soil pH was determined using a suspension of 10 g of soil in 50 ml of distilled water. The solution was allowed to stand for 30 min and stirred with a glass rod and the reading taken using Orion Research analog pH meter/Model 301. (Blakemore *et al.*, 1987).

3.6.2 Organic carbon and Organic matter Determination

One gramme of soil sample was weighed into 500 ml Erlenmeyer flask. 10 ml of 1.0 N potassium dichromate was added to it and swirled to mix, 20 ml of conc H_2SO_4 was also added and mixed gently for 30 min. The mixture was diluted to 200 ml with distillled water. Then, 10 ml of 85% orthophosporic acid (H_3PO_4), 0.2 g of NaF and 3-4 drops of ferroin indicator was added and the content titrated with 0.1N of ammonium ferrous sulphate (FAS) until the solution turned to wine-red, indicating the endpoint.

Milliequivalent of readily oxidizable material per gramme of soil (meq.OX./g)

Where: X= volume of FAS used in titration of reagent blank

Y= volume of FAS used in titration of sample

W= weight of the soil used

% OC =Meq. Ox./g. × 12/4000 × 1/0.77 × 100

= meq. Ox./g. × 0.39

Where: 12/4000= milliquivalent weight of carbon

1/0.77= factor for converting the carbon that actually oxidized to total carbon

100= factor to change from decimal fraction to percentage (%)

% OM = %OC × 1/0.58

% OC × 1.724

Where 1.724 is the factor for converting organic carbon to organic matter.

3.7: Percentage Nitrogen Determination in Soil and Vegetable Samples

One gramme of soil and vegetable samples were weighed into separate Kjeldahl digestion flasks. A little scoop of digestion catalyst was added after which 20 ml of concentrated H_2SO_4 was also added to the mixture after which the flasks were transferred to Kjeldahl digestion system (Tecator digestion system 1007 digester) and heated for 2 hrs. The resulting mixture was allowed to cool and later made up to 100 ml with distilled water. Twenty millilitres of 2% boric acid (plus indicator) was pipetted into 100 ml Erlenmeyer flasks. The 100ml flasks were placed under the receiving tube of the distillation unit after which 10 ml aliquots of the samples were pippeted into the distillation unit and 10 ml of 40% NaOH added. The distillation was allowed to continue until the content of 100 ml Erlenmeyer flasks was about 75 ml. The distillates were later titrated with standard HCl (0.01N) until the blue colour disappeared.

Calculation:

$$\%N = \frac{\text{Titre value} \times \text{concentration of acid} \times 0.014 \times \text{dilution factor} \times 100}{\text{Weight of sample taken}}$$

% Nitrate = %N × 4.423 (factor for converting from % N to % Nitrate)

% nitrate was multiplied by 10,000 which is the ratio between 100 and 1000000 to convert to mg/kg.

3.8 Digestion of Samples

One gramme of both soil and vegetable samples were placed into 100 ml beaker separately to which 15 ml of trio-acid mixture (70% HNO_3, 65% $HClO_4$ and 70% H_2SO_4) was added in ratio 5:1:1. The mixture was digested at 80^oC until the solution became clear. The resulting solution was filtered and diluted to 50 ml and later analysed for metals concentration (Ogunfowokan *et al*., 2013).

3.9 Atomic Absorption Spectrophotometric Determination of Heavy Metals

The digested soil and vegetable samples were analysed for their heavy metals (As, Cd, Cu, Pb and Zn) content using Atomic Absorption Spectrophotometer PG 990 model available at the Central Science Laboratory, O.A.U., Ile-Ife. All concentrations were reported in mg/kg.

3.10 Assessment of the Impact of Peri-urban Farming Activites on Soil Environment

3.10.1 Pollution Load Index (PLI)

Each peri-urban farm was evaluated for the extent of heavy metal pollution. The degree of soil pollution for each metal was measured using the pollution load index (PLI) technique depending on soil metal concentrations. The following modified equation was used to assess the PLI level in soils.

$$PLI = \frac{C_{soil}\ (Samples)}{C_{reference}\ (References)}$$ (Liu *et al.*, 2005)

Where C_{soil} (Samples) and $C_{reference}$ (Reference) represent heavy metal concentrations in the soil samples and reference soil, respectively. A value of PLI < 1 denotes perfection and PLI > 1would indicate deterioration of site quality (Liu *et al*., 2005).

3.11 Health Risk Assessments of Metals

3.11.1 Transfer Factor (TF)

Metals concentration in the extracts of soils and vegetables were calculated on the basis of dry weight. The plant concentration factor (PCF) was calculated as follows:

$$PCF = \frac{C_{plant}}{C_{soil}}$$ (Ciu *et al.*, 2005)

Where C_{plant} and C_{soil} represent heavy metal concentration in extracts of vegetables and soils on dry weight basis, respectively.

3.11.2 Daily Intake of Metals (DIM)

The daily intake (DIM) of heavy metals (As, Cd, Cu, Pb, Zn) depended on the metal concentration in vegetables and the amount of consumption of the respective vegetables. The DIM of metals was determined by the following equation.

Daily intake of metals (DIM) = DVC × VMC

DVC = Daily vegetable consumption; VMC = Mean vegetable metal concentration (mg/kg)

Where daily vegetable consumption was taken as 98 g of vegetables per person per day as set by the FAO/WHO (1999), for heavy metals intake based on body weight for an average adult (60 kg body weight).

3.11.3 Health Risk Index (HRI)

The health risk index (HRI) for the consumption of contaminated vegetables was assessed based on the food chain and the reference oral dose (RfD) for each metal. The HRI <1 means the exposed population is assumed to be safe.

$$HRI = \frac{DIM}{RfD}$$

Where DIM is the daily intake of metals and RfD is the reference oral dose for each metal. Reference oral dose are 0.003, 0.001, 0.04, 0.004 and 0.3 mg/kg/day for As, Cd, Cu, Pb and Zn respectively (FAO/WHO, 2013).

3.11.4 Hazard Index (HI)

Estimation of potential health risk arising from consumption of more than one heavy metals in vegetables, the hazard index (HI) was developed by USEPA (2002) and was calculated as the total sum of the potential health risk index (HRI) of all the metals examined.

$$HI = \sum HRI_{Cd} + HRI_{Cu} + HRI_{Pb} + HRI_{Zn}$$

The magnitude of hazard index is assumed to be proportional to the extent of adverse effects or toxicity of the vegetables consumed.

3.12 Data Analysis

Descriptive statistics such as mean, standard deviation and range were used to summarize data collected from sampling sites. Statistical analysis for the cross sectional survey was carried out using Predictive Analytical software for Windows (SAS version 9.2). Analysis of variance ($p < 0.05$), cluster analysis and Pearson correlation coefficient were used to test for association between the different variables.

CHAPTER FOUR

RESULTS

4.1: Farming and Production Practices Peculiar to Each Peri-urban Farm Studied

A total of fifteen peri-urban farmers were purposively sampled using a structured questionnaire. With regard to farm practices, planting were either on raised beds or ridges, 93% of the farmers carried out weeding by hand pulling while 7% of the farmers applied herbicide. Sixty percent of the farmers enhanced soil fertility by applying inorganic fertilizer, 13% of the farmers applied both poultry manure and inorganic fertilizers while 27% of the farmers depended on natural fertility. Sixty seven percent of the farmers irrigated with nearby streams, 7% with shallow well, 13% with river tributaries and 13% with waste water. Conveyance is by bucket/basin, drainage channels and motorized pumps. Table 4.1 shows the location, farming and production practices peculiar to each peri-urban farm studied.

4.2: Chemical Parameters of Peri-urban Farm Soils and Reference Soil

Table 4.2 shows the chemical characteristics of peri-urban farm soils and reference soil. In this study, soil pH ranged from 5.24 -7.87 indicating a moderately acidic to slightly alkaline pH. Total organic carbon in the peri-urban farm soils under investigation ranged from 0.68-6.32%, indicating a low to high amount of organic carbon based on the classification of Enwezor *et al.* (1998). Organic matter in soil samples ranged from low to high with values which varied between 1.18-10.87%. The %N content of peri-urban farm soils ranged from 0.06-0.54%. The values obtained for OC, OM, %N in peri-urban farm soils were higher than that of the reference soil.

Table 4.1: Location of Peri-urban farms, Farming and Production Practices Peculiar to Peri-urban Farms Studie

Table 4.2: Chemical Parameters of Peri-urban Farm Soils and Reference Soil

Farms	pH	% OC	% OM	% N
1	5.77	1.99	3.43	0.17
2	7.09	1.21	2.08	0.10

3	5.24	4.49	7.73	0.39
4	7.24	1.05	1.80	0.09
5	5.75	2.01	3.46	0.30
6	7.23	1.15	1.97	0.10
7	7.71	0.74	1.28	0.06
8	7.27	6.32	10.87	0.54
9	7.03	1.03	1.79	0.09
10	7.82	1.68	2.88	0.14
11	7.29	3.46	5.80	0.29
12	6.52	1.25	2.15	0.11
13	7.86	0.70	1.21	0.06
14	7.87	0.68	1.18	0.06
15	7.51	1.53	2.66	0.13
Ref. soil	7.79	0.41	0.72	0.04

OC= Organic carbon OM = Organic matter % N = percentage nitrogen
Ref. soil = reference Soil
Farm 1= Owode-Ede, by the road side
Farm 2 = outskirt of Ede
Farm 3= Ilo-Ajegunle
Farm 4= Ila-Orangun, near an abandoned waste depot
Farm 5= Ila-Orangun
Farm 6 = Ido-Ijesa, near fish ponds
Farm 7 = outskirt of Ile-Ife
Farm 8= by the road side, along Ede-road, Ile-Ife
Farm 9 = along Osogbo/Ilie road
Farm 10= Outskirt of Iwo town, near a waste depot
Farm 11= between Telemu and Iwo
Farm 12= along Osogbo/Ikirun road
Farm 13= outskirt of Osogbo town
Farm 14= along Ikirun/Inisha road
Farm 15= outskirt of Osogbo town

4.3: Nitrate Concentration in Peri-urban farm Soils, Vegetables and Reference Samples

Table 4.3 shows the concentration levels of nitrate ion in soils and vegetables collected from peri-urban farms and reference samples. Nitrate levels varied between 20.45 -240.52

mg/kg and 214.15-1,204.50 mg/kg in soil and vegetable samples from peri-urban farms respectively. Vegetables from peri-urban farms were within the permissible limit (2500-3000) mg/kg for nitrate ion in leafy vegetables by WHO/EC (1993).

4.4: Heavy Metals Concentration in Peri-urban Farm soils, Vegetables and Reference Samples

Mean heavy metals (Cd, Cu, Pb and Zn) concentration in studied peri-urban farm soils, vegetables and reference samples are shown in Tables 4.3-4.5. Concentration of heavy metals in the soils of peri-urban farms ranged between 0.18-0.63, 2.40-56.17, 0.70-36.75 and 30-300 mg/kg for Cd, Cu, Pb and Zn respectively. Concentration of heavy metals in the soils of farm 1, 7, 9, 11 varied in the order Zn > Pb > Cu > Cd while heavy metals concentration in Amaranthus and Corchorus obtained from these farms followed the order Zn > Cu > Pb > Cd. Mean concentration of heavy metals in the soils of farms 2, 3, 4, 5, 10, 12, 13, 14, 15 and reference soil varied in the order Zn > Cu > Pb > Cd. Amaranthus and Corchorus collected from these farms showed similar trend. Reference Amaranthus and Corchorus also showed similar trend. Mean concentration of heavy metals in the soil of farm 6 varied in the order Cu > Zn > Pb > Cd. A trend of Zn > Cu >Pb > Cd was observed in Amaranthus and Corchorus from this farm. Heavy metals concentration in the soil and Corchorus from farm 8 varied in the order Zn > Cu > Pb > Cd while in Amaranthus, heavy metal concentration was in the order Zn > Pb > Cu > Cd.

Table 4.3: Mean Nitrate (NO_3^-) Concentration (mg/kg) in Peri-urban Farm Soils, Vegetables and Reference Samples

Farms	Soil (mean ± SD)	Amaranthus (mean ± SD)	Corchorus (mean ± SD)
1	75.57 ± 0.03	1,145.02 ± 1.98	684.00 ± 3.90
2	45.49 ± 0.50	839.50 ± 2.50	1,053.72 ±2.70
3	170.36± 0.37	715.40 ± 2.40	502.50 ± 5.00
4	40.02 ± 0.23	589.00 ± 0.00	544.45 ± 9.50
5	132.28 ±1.29	589.60 ± 6.00	1,002.50 ±2.50
6	43.15 ± 0.15	1,174.00 ± 4.00	899.50 ±5.00
7	28.40 ± 0.10	1,055.75 ± 7.50	647.50 ± 5.80
8	240.52 ±0.52	523.75 ± 6.70	214.15 ± 1.65
9	20.45 ± 0.55	864.00 ± 4.00	538.75 ± 1.25
10	63.61 ± 0.08	942.50 ± 5.20	844.75 ± 7.50
11	128.13 ±0.14	862.75 ± 5.65	774.35 ± 3.50
12	47.56 ± 0.24	1,103.12 ±1.25	1,204.50 ±4.50
13	26.27 ± 0.27	1,025.00 ±2.01	527.75 ± 2.50
14	59.51 ±0.02	747.37 ± 3.70	497.12 ±1.25
15	32.84 ± 0.66	745.02 ± 4.70	761.54 ±3.61
Ref. Sap.	15.67 ± 0.23	410.00 ± 1.00	232.00 ± 9.50

SD = Standard deviation
Ref. Sap = reference soil and vegetable samples
Farm 1= Owode-Ede, by the road side
Farm 2 = outskirt of Ede
Farm 3= Ilo-Ajegunle
Farm 4= Ila-Orangun, near an abandoned waste depot
Farm 5= Ila-Orangun
Farm 6 = Ido-Ijesa, near fish ponds
Farm 7 = outskirt of Ile-Ife
Farm 8= by the road side, along Ede-road, Ile-Ife
Farm 9 = along Osogbo/Ilie road
Farm 10= Outskirt of Iwo town, near a waste depot
Farm 11= between Telemu and Iwo
Farm 12= along Osogbo/Ikirun road
Farm 13= outskirt of Osogbo town
Farm 14= along Ikirun/Inisha road
Farm 15= outskirt of Osogbo town

Table 4.4: Mean Heavy Metals Concentration (mg/kg) in Peri-urban Farm Soils and Reference Soil

Farms	As (mean±SD)	Cd (mean±SD)	Cu (mean±SD)	Pb (mean±SD)	Zn (mean ±SD)
1	BDL	0.18 ± 0.05	26.82 ± 0.05	36.75 ± 0.30	123.00 ± 5.25
2	BDL	0.35 ± 0.08	17.20 ± 0.10	10.57 ± 0.73	196.00 ± 4.50
3	BDL	0.20 ± 0.50	21.73 ± 0.18	4.50 ± 0.30	30.50 ± 1.50
4	BDL	0.23 ± 0.10	23.10 ± 0.10	11.78 ± 0.25	97.75 ± 1.00
5	BDL	0.33 ± 0.15	5.35 ± 0.13	13.45 ± 0.05	46.00 ± 1.50
6	BDL	0.28 ± 0.08	56.17 ± 0.50	5.52 ± 0.20	30.00 ± 2.00
7	BDL	0.38 ± 0.03	13.90 ± 0.08	15.00 ± 0.35	108.75 ± 3.75
8	BDL	0.23 ± 0.03	7.38 ± 0.13	5.10 ± 0.18	49.10 ± 5.25
9	BDL	0.28 ± 0.05	4.25 ± 0.05	10.78 ± 0.08	60.50 ± 0.32
10	BDL	0.63 ± 0.05	42.45 ± 0.25	33.83 ± 0.20	300.75 ± 2.75
11	BDL	0.45 ± 0.05	25.58 ± 0.05	36.73 ± 0.30	256.00 ± 8.75
12	BDL	0.20 ± 0.10	2.40 ± 0.05	0.70 ± 0.30	68.75 ± 3.75
13	BDL	0.45 ± 0.13	26.03 ± 0.08	16.28 ± 0.48	253.00±17.50
14	BDL	0.22 ± 0.01	4.68 ± 0.02	5.30 ± 0.20	102.00 ± 0.01
15	BDL	0.43 ± 0.01	38.12 ± 0.01	5.46 ± 0.01	50.00 ± 0.02
Ref. soil	BDL	0.12 ± 0.01	4.95 ± 0.08	4.58 ± 0.75	69.75 ± 1.00
Limit	-	3.0[a]	140[a]	300[a]	300[a]
Limit	-	3.0[b]	140[b]	300[b]	300[b]

a = FAO/WHO (2002) permissible limit b = EU (2006) permissible limit Ref. soil = reference soil

SD = standard deviation

BDL = below detection limit

Farm 1= Owode-Ede, by the road side

Farm 2 = outskirt of Ede

Farm 3= Ilo-Ajegunle

Farm 4= Ila-Orangun, near an abandoned waste depot

Farm 5= Ila-Orangun

Farm 6 = Ido-Ijesa, near fish ponds

Farm 7 = outskirt of Ile-Ife

Farm 8= by the road side, along Ede-road, Ile-Ife

Farm 9 = along Osogbo/Ilie road

Farm 10= Outskirt of Iwo town, near a waste depot

Farm 11= between Telemu and Iwo

Farm 12= along Osogbo/Ikirun road

Farm 13= outskirt of Osogbo town

Farm 14= along Ikirun/Inisha road

Farm 15= outskirt of Osogbo town

Table 4.5: Mean Heavy Metals Concentration (mg/kg) in Amaranthus Produced from Different Peri-urban Farms and Reference Amaranthus

Farms	As (mean±SD)	Cd (mean±SD)	Cu (mean±SD)	Pb (mean±SD)	Zn (mean ±SD)
1	BDL	0.80 ± 0.08	5.03 ± 0.10	2.65 ± 0.23	95.00 ± 20.00
2	BDL	0.83 ± 0.10	5.98 ± 0.13	4.95 ± 0.23	158.80 ± 3.25
3	BDL	0.73 ± 0.05	6.60 ± 0.01	3.10 ± 0.10	87.50 ± 1.25
4	BDL	0.55 ± 0.08	9.38 ± 0.15	8.28 ± 0.35	108.00 ± 3.50
5	BDL	0.30 ± 0.05	0.85 ± 0.10	0.80 ± 0.18	41.75 ± 1.75
6	BDL	0.58 ± 0.05	3.30 ± 0.08	2.10 ± 0.20	123.00 ± 2.00
7	BDL	0.28 ± 0.08	1.30 ± 0.08	1.18 ± 0.01	61.75 ± 0.18
8	BDL	0.70 ± 0.01	9.60 ± 0.13	11.55±0.10	108.75 ± 1.75
9	BDL	0.55 ± 0.15	3.65 ± 0.05	2.63 ± 0.38	107.50 ± 3.50
10	BDL	0.21 ± 0.01	5.20 ± 0.14	4.81 ± 0.01	105.00 ± 0.02
11	BDL	0.50 ± 0.13	4.58 ± 0.08	4.45 ± 0.40	101.50 ±0.25
12	BDL	0.55 ± 0.25	4.20 ± 0.08	3.00 ± 0.15	76.25 ± 3.25
13	BDL	0.35 ± 0.10	4.78 ± 0.05	1.08 ± 0.10	77.25 ± 2.25
14	BDL	0.21 ± 0.01	3.52 ± 0.01	2.44 ± 0.01	84.98 ± 0.01
15	BDL	0.23 ± 0.01	5.45 ± 0.02	3.42 ± 0.02	32.00 ± 0.01
Ref. amar	BDL	0.15 ± 0.01	3.00 ± 0.08	2.03 ± 0.01	43.00 ± 1.75
Limit	0.43[a]	0.20[a]	40.00[a]	0.30[a]	50.00[a]
Limit	-	0.20[b]	20.00[b]	0.43[b]	50.00[b]

a= FAO/WHO(2002) permissible limit b=EU (2006) permissible limit Ref. amar = reference Amaranthus
SD = standard deviation BDL = below detection limit
Farm 1= Owode-Ede, by the road side Farm 2 = outskirt of Ede
Farm 3= Ilo-Ajegunle Farm 4= Ila-Orangun, near an abandoned waste depot
Farm 5= Ila-Orangun Farm 6 = Ido-Ijesa, near fish ponds
Farm 7 = outskirt of Ile-Ife Farm 8= by the road side, along Ede-road, Ile-Ife
Farm 9 = along Osogbo/Ilie road Farm 10= Outskirt of Iwo town, near a waste depot

Farm 11= between Telemu and Iwo
Farm 12= along Osogbo/Ikirun road
Farm 13= outskirt of Osogbo town
Farm 14= along Ikirun/Inisha road
Farm 15= outskirt of Osogbo town

Table 4.6: Mean Heavy Metals Concentration (mg/kg) in Corchorus produced from different Peri-urban Farms and Reference Corchorus

Farms	As (mean±SD)	Cd (mean±SD)	Cu (mean±SD)	Pb (mean±SD)	Zn (mean ±SD)
1	BDL	0.38 ± 0.10	10.03 ± 0.03	2.53 ± 0.30	60.50 ± 2.00
2	BDL	0.55 ± 0.03	10.33 ± 0.05	4.70 ± 0.18	88.50 ± 3.50
3	BDL	0.39 ± 0.08	6.76 ± 0.03	1.54 ± 0.18	57.61 ± 1.05
4	BDL	0.28 ± 0.08	10.45 ±0.04	2.18 ± 0.45	18.25 ± 0.15
5	BDL	0.45 ± 0.10	8.83 ± 0.15	1.15 ± 0.15	39.25 ± 2.75
6	BDL	0.38 ± 0.01	8.75 ± 0.10	1.35 ± 0.18	57.50 ± 2.75
7	BDL	0.22 ± 0.01	2.53 ± 0.03	0.87 ± 0.01	51.60 ± 0.02
8	BDL	0.23 ± 0.01	9.82 ± 0.02	4.15 ± 0.02	23.00 ± 0.06
9	BDL	0.30 ± 0.10	3.41 ± 0.01	2.43 ± 0.01	40.22 ± 0.01
10	BDL	0.58 ± 0.08	7.60 ± 0.05	3.50 ± 0.30	57.50 ± 3.50
11	BDL	0.48 ± 0.08	7.78 ± 0.10	3.00 ± 0.13	50.00 ± 2.50
12	BDL	0.30 ± 0.03	5.45 ± 0.10	2.70 ± 0.35	58.75 ± 1.00
13	BDL	0.30 ± 0.10	6.45 ± 0.08	2.85 ± 0.23	60.50 ± 1.75
14	BDL	0.10 ± 0.01	4.22 ±0.01	1.38 ± 0.01	25.60 ± 0.03
15	BDL	0.11 ± 0.01	10.08 ± 0.01	0.06 ± 0.01	14.12 ± 0.01
Ref. cor	BDL	0.003±0.01	0.10 ± 0.01	0.20 ± 0.01	0.60 ± 0.14
Limit	0.43[a]	0.20[a]	40.00[a]	0.30[a]	50.00[a]
Limit	-	0.20[b]	20.00[b]	0.43[b]	50.00[b]

a = FAO/WHO (2002) permissible limit b = EU (2006) permissible limit Ref. Cor = reference corchorus
SD = standard deviation
BDL = below detection limit
Farm 1= Owode-Ede, by the road side
Farm 2 = outskirt of Ede
Farm 3= Ilo-Ajegunle
Farm 4= Ila-Orangun, near an abandoned waste depot
Farm 5= Ila-Orangun
Farm 6 = Ido-Ijesa, near fish ponds

Farm 7 = outskirt of Ile-Ife
Farm 8= by the road side, along Ede-road, Ile-Ife
Farm 9 = along Osogbo/Ilie road
Farm 10= Outskirt of Iwo town, near a waste depot
Farm 11= between Telemu and Iwo
Farm 12= along Osogbo/Ikirun road
Farm 13= outskirt of Osogbo town
Farm 14= along Ikirun/Inisha road
Farm 15= outskirt of Osogbo town

In soil and vegetable samples collected from all peri-urban farms studied, As was below detection limit. Heavy metals concentration in the soil of peri-urban farms were below the FAO/WHO (2002) and EU (2006) permissible levels for metals in agricultural soil. Cadmium concentrations in Amaranthus and Corchorus exceeded the permissible limit set by FAO/WHO and EU (2006) for Cd in leafy vegetables except in Corchorus collected from farms 14 and 15. Zinc concentration in Amaranthus and Corchorus also exceeded these limits for Zn in leafy vegetables except in Amaranthus collected from farms 5 and 15 and Corchrous collected from farms 4, 5, 8, 9, 11 and 15 respectively. Concentrations of Pb in Amaranthus and Corchorus exceeded the FAO/WHO and EU (2006) limits for Pb in vegetables while concentrations of Cu in Amaranthus and Corchorus were below the limits. Amaranthus had the highest concentration for all investigated heavy metals except Cu (Fig. 4.6). There was difference in heavy metals concentration in reference soil and vegetable samples compared to heavy metals concentration in soil and vegetable samples from peri-urban farms with significant values ($P < 0.05$).

4.5: Hierarchical Cluster Analysis of Heavy Metals in Peri-urban Farm Soils and Vegetables

The hierarchical cluster analysis using nearest neighbor approach produced five cluster diagrams which are shown in Fig. 4.1- 4.5. Hierarchical cluster analysis was executed to determine the correspondence between sampling stations in the study area. Cluster diagram based on all investigated metals classified peri-urban farms into two distinct clusters. Cluster 1 shows that farms 3, 4, 8, 6 and 9 are closely related. Cluster 2 shows that farms 1, 2, 5, 7, 10, 11,12, 13, 14 and 15 are also related. According to Cd, Cu, Pb and Zn concentrations, HCA categorized each peri-urban farm into four distinctive cluster diagrams based on pollution magnitude.

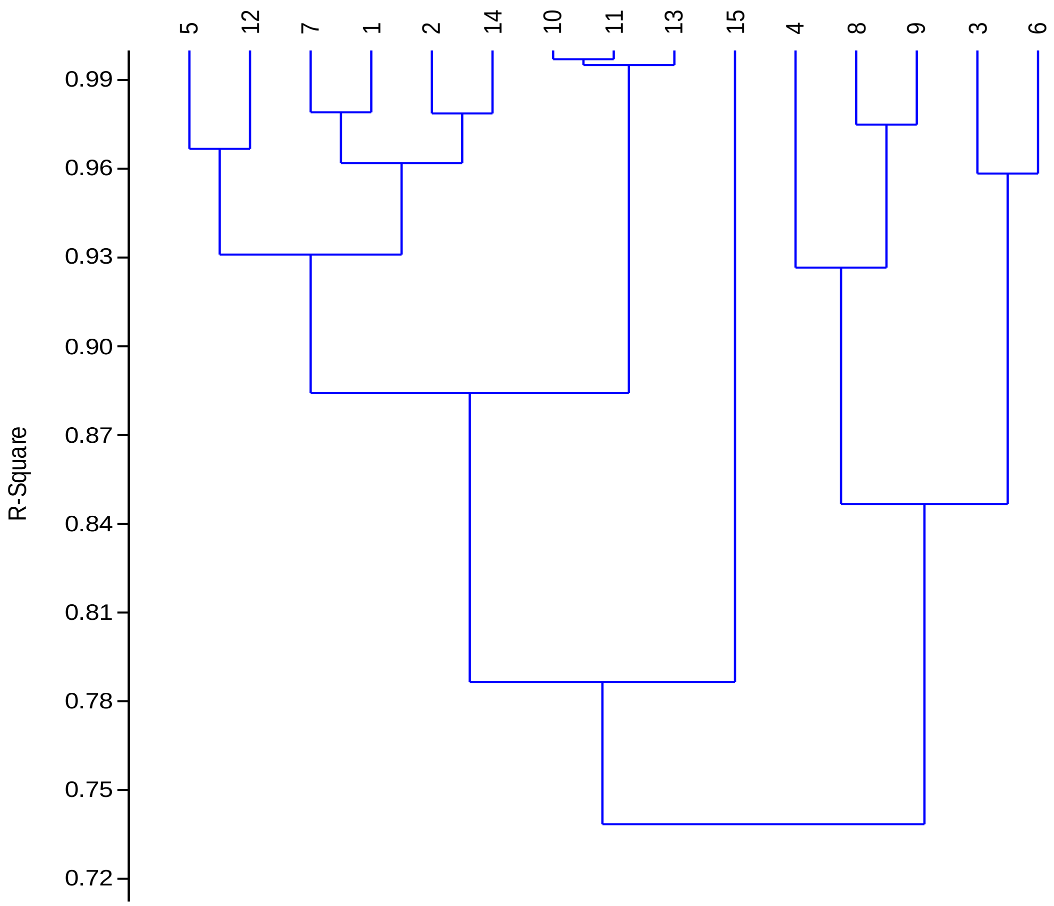

Fig 4.1: Cluster Diagram Based on All Investigated Heavy Metals in Peri-urban Farm Soil and Vegetable Samples

LEGEND

Farm 1= Owode-Ede, by the road side
Farm 2 = outskirt of Ede
Farm 3= Ilo-Ajegunle
Farm 4= Ila-Orangun, near an abandoned waste depot
Farm 5= Ila-Orangun
Farm 6 = Ido-Ijesa, near fish ponds
Farm 7 = outskirt of Ile-Ife
Farm 8= by the road side, along Ede-road, Ile-Ife

Farm 9 = along Osogbo/Ilie road
Farm 10= Outskirt of Iwo town, near a waste depot
Farm 11= between Telemu and Iwo
Farm 12= along Osogbo/Ikirun road
Farm 13= outskirt of Osogbo town
Farm 14= along Ikirun/Inisha road
Farm 15= outskirt of Osogbo town

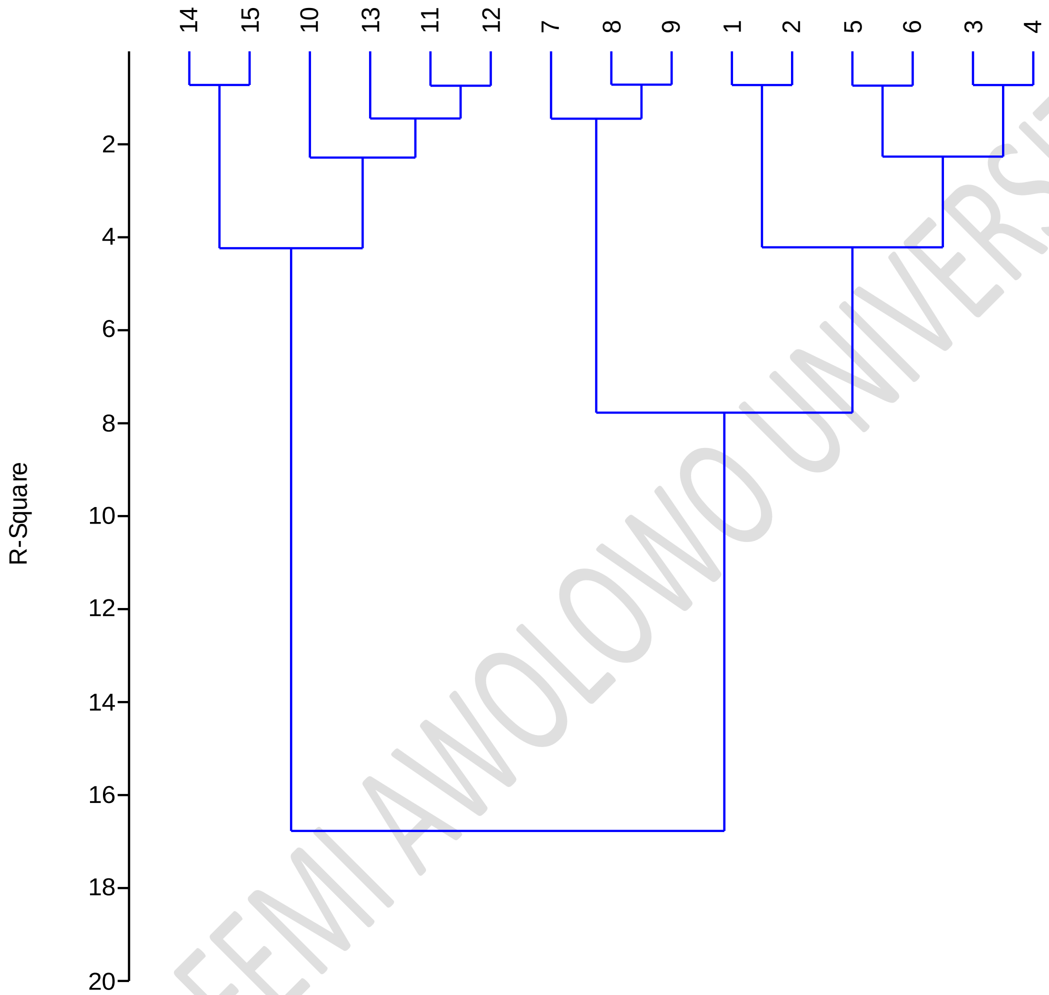

Fig 4.2: Cluster Diagram based on Cd Concentration in Peri-urban Farm Soil and Vegetable Samples

LEGEND

Farm 1= Owode-Ede, by the road side
Farm 2 = outskirt of Ede
Farm 3= Ilo-Ajegunle
Farm 4= Ila-Orangun, near an abandoned waste depot
Farm 5= Ila-Orangun
Farm 6 = Ido-Ijesa, near fish ponds

Farm 7 = outskirt of Ile-Ife
Farm 8= by the road side, along Ede-road, Ile-Ife
Farm 9 = along Osogbo/Ilie road
Farm 10= Outskirt of Iwo town, near a waste depot
Farm 11= between Telemu and Iwo
Farm 12= along Osogbo/Ikirun road
Farm 13= outskirt of Osogbo town
Farm 14= along Ikirun/Inisha road
Farm 15= outskirt of Osogbo town

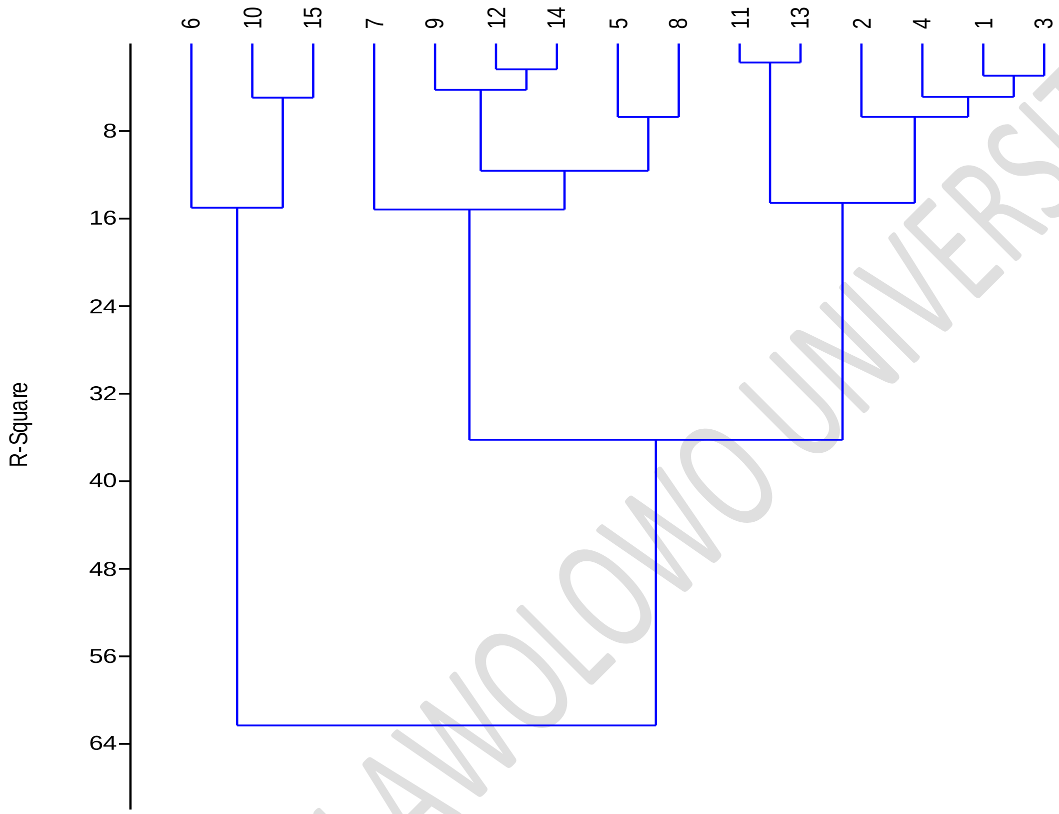

Fig 4.3: Cluster Diagram Based on Cu Concentration in Peri-urban Farm Soil and Vegetable Samples

LEGEND

Farm 1= Owode-Ede, by the road side
Farm 2 = outskirt of Ede
Farm 3= Ilo-Ajegunle
Farm 4= Ila-Orangun, near an abandoned waste depot
Farm 5= Ila-Orangun
Farm 6 = Ido-Ijesa, near fish ponds
Farm 7 = outskirt of Ile-Ife
Farm 8= by the road side, along Ede-road, Ile-Ife
Farm 9 = along Osogbo/Ilie road
Farm 10= Outskirt of Iwo town, near a waste depot

Farm 11= between Telemu and Iwo
Farm 12= along Osogbo/Ikirun road
Farm 13= outskirt of Osogbo town
Farm 14= along Ikirun/Inisha road
Farm 15= outskirt of Osogbo town

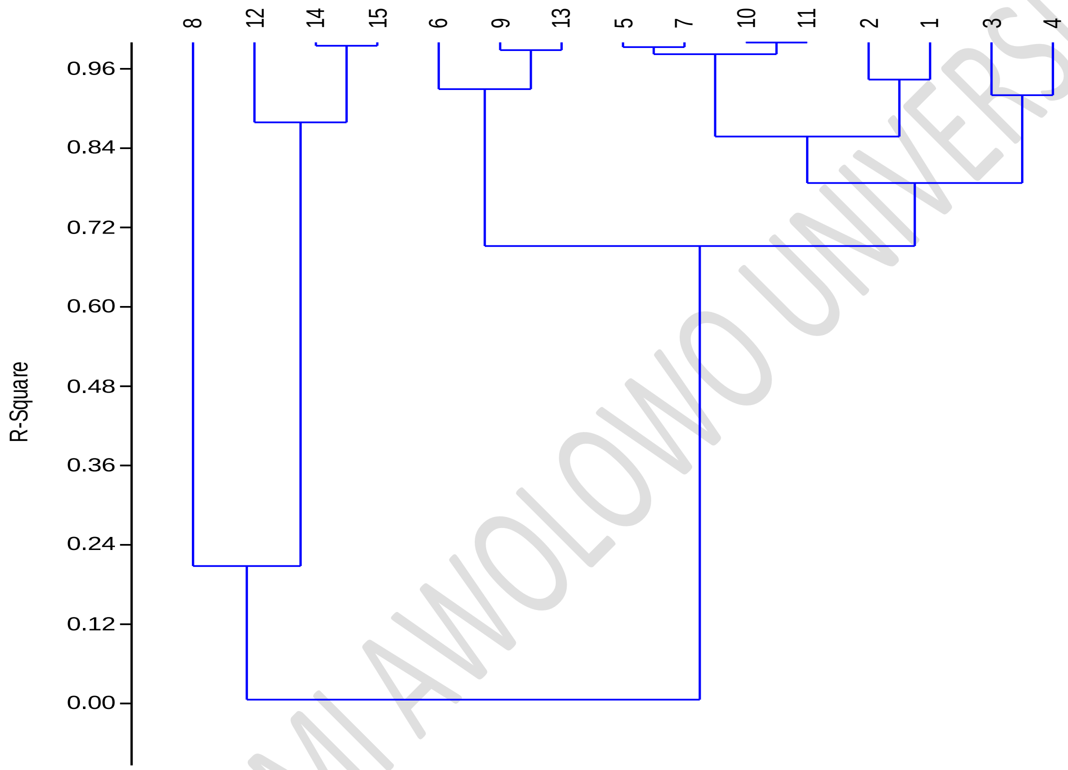

Fig 4.4: Cluster Diagram Based on Pb Concentration in Peri-urban Farm Soil and Vegetable Samples

LEGEND

Farm 1= Owode-Ede, by the road side
Farm 2 = outskirt of Ede
Farm 3= Ilo-Ajegunle
Farm 4= Ila-Orangun, near an abandoned waste depot
Farm 5= Ila-Orangun
Farm 6 = Ido-Ijesa, near fish ponds
Farm 7 = outskirt of Ile-Ife
Farm 8= by the road side, along Ede-road, Ile-Ife

Farm 9 = along Osogbo/Ilie road
Farm 10= Outskirt of Iwo town, near a waste depot
Farm 11= between Telemu and Iwo
Farm 12= along Osogbo/Ikirun road
Farm 13= outskirt of Osogbo town
Farm 14= along Ikirun/Inisha road
Farm 15= outskirt of Osogbo town

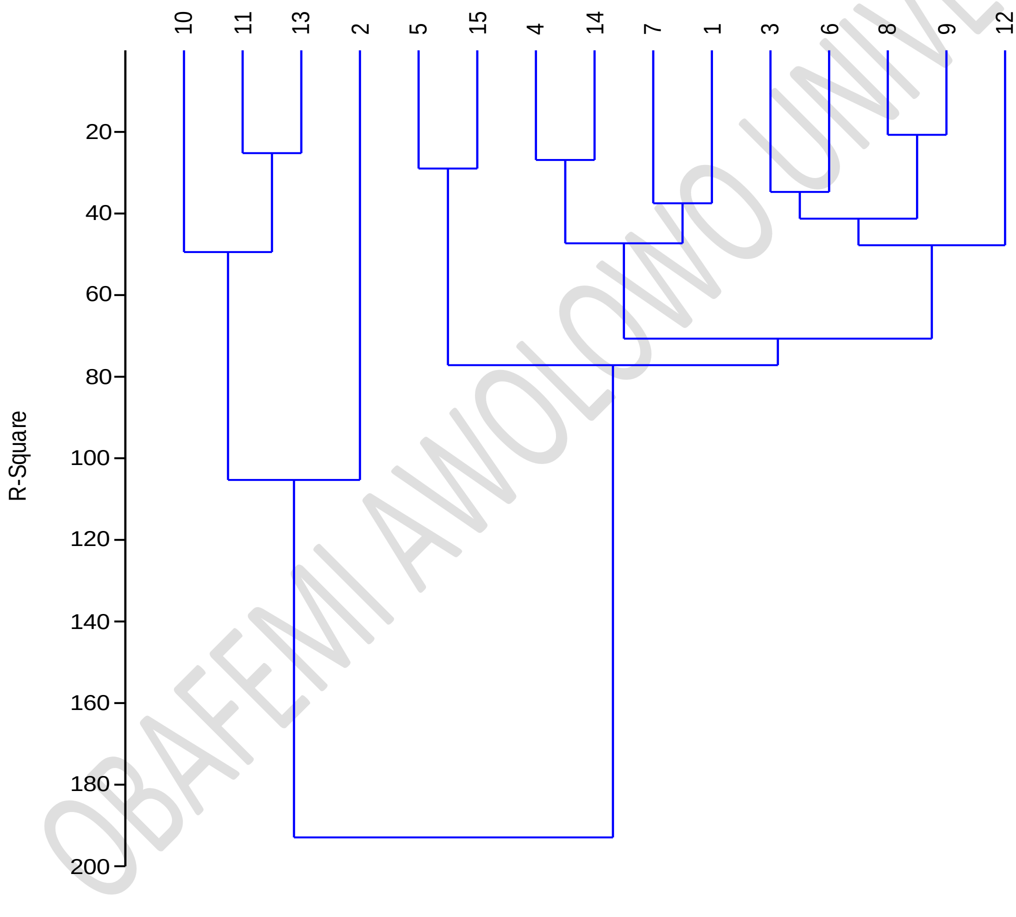

Fig 4.5: Cluster Diagram Based on Zn Concentration in Peri-urban Farm Soil and Vegetable Samples

LEGEND

Farm 1= Owode-Ede, by the road side
Farm 2 = outskirt of Ede
Farm 3= Ilo-Ajegunle
Farm 4= Ila-Orangun, near an abandoned waste depot
Farm 5= Ila-Orangun
Farm 6 = Ido-Ijesa, near fish ponds
Farm 7 = outskirt of Ile-Ife
Farm 8= by the road side, along Ede-road, Ile-Ife
Farm 9 = along Osogbo/Ilie road
Farm 10= Outskirt of Iwo town, near a waste depot
Farm 11= between Telemu and Iwo
Farm 12= along Osogbo/Ikirun road
Farm 13= outskirt of Osogbo town
Farm 14= along Ikirun/Inisha road
Farm 15= outskirt of Osogbo town

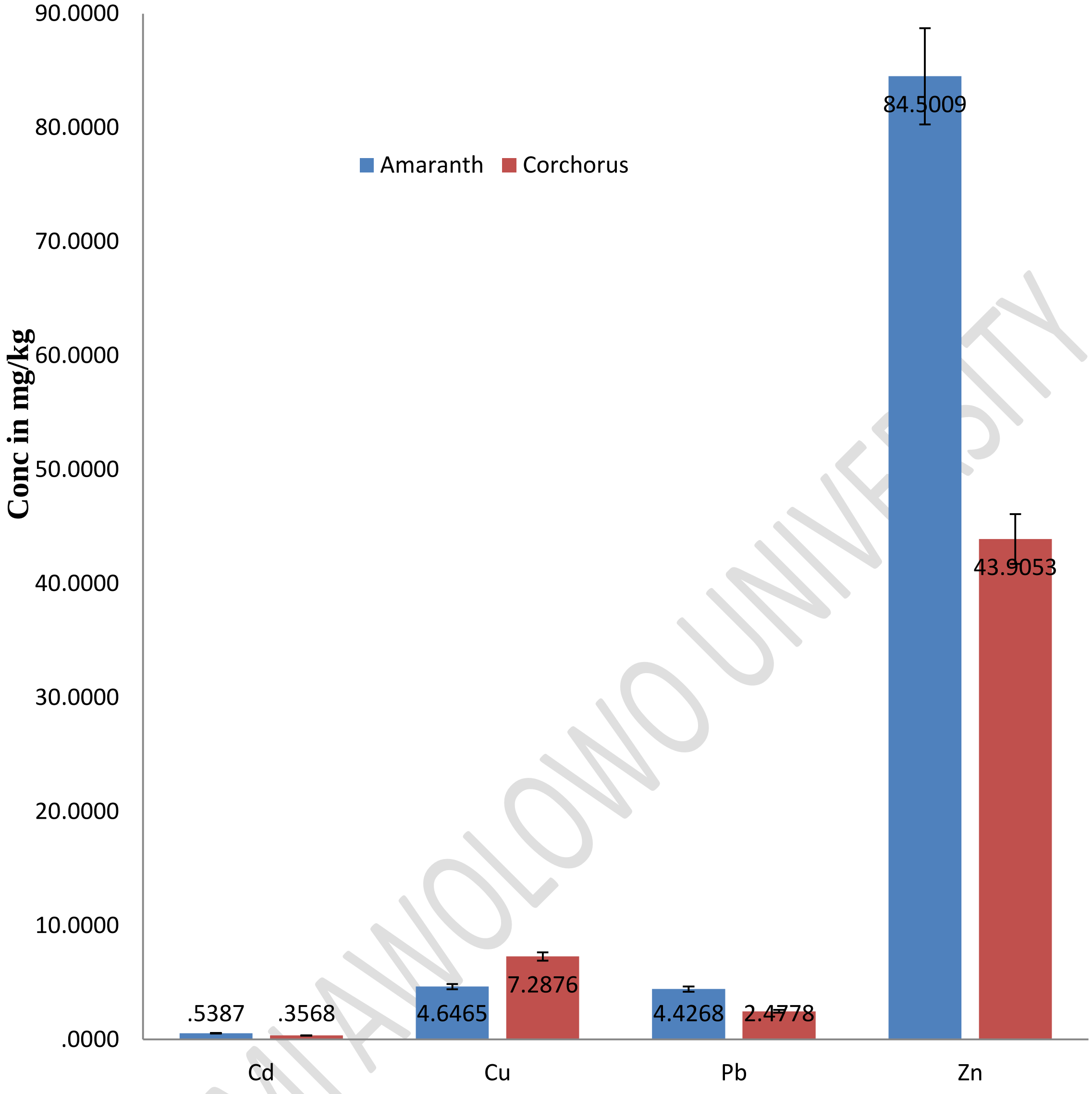

Fig 4.6: Comparison of Heavy Metals Uptake by Vegetables

4.6 Pollution Load Index (PLI)

Table 4.7 shows the result of the PLI for the five metals studied at the various farms. The PLI for Cd, Cu, Pb and Zn ranged from 1.51-5.25, 0.86-11.34, 0.15-8.02 and 0.44-6.49, respectively. The degree of contamination is in the order farm 10 > 11 > 13 > 1> 6 > 15 > 2 > 4 > 7 > 3 > 5 > 9 > 8 > 14 > 12. The soils of peri-urban farms studied were moderately enriched with Cd and Zn but strongly enriched with Cu and Pb.

4.7 Transfer Factor of Individual Metal to Vegetables (TF)

The transfer factor as computed indicated the level of metal in the edible plant as a fraction of the soil total. The plant transfer factor is presented in Tables 4.8 and 4.9. The transfer factor for Cd, Cu, Pb and Zn ranged from 0.07-4.44, 0.06-0.41, 0.07-4.28 and 0.31-4.08 mg/kg, respectively for Amaranthus while it ranged from 0.11-2.11, 0.06-2.27, 0.06-3.86 and 0.13-2.63 mg/kg, respectively for Corchorus. Cadmium had the highest transfer factor followed by Zn while Cu and Pb had the lowest. Transfer Factor values showed metal uptake by vegetables in the order Cd > Zn > Pb > Cu. Amaranthus had the highest TF for all metals except Cu. Table 4.10 shows the test of correlation between heavy metals concentration in peri-urban farm soil and vegetable samples. Pearson correlation detected positive correlations which were statistically significant at ($p < 0.05$) between Cd, Pb and Zn concentrations in the soil of peri-urban farms studied. Pearson correlation also detected positive correlation between Cd, Pb and Zn concentration in Corchorus. Copper and Pb concentrations in Amaranthus and Corchorus also correlated significantly.

Table 4.7: Pollution Load Index of Heavy Metals (PLI)

Farm	As	Cd	Cu	Pb	Zn
1	-	1.51	5.45	8.02	1.76
2	-	2.92	3.47	2.31	2.81
3	-	1.66	4.39	0.98	0.44
4	-	1.91	4.66	2.57	1.01
5	-	2.75	1.08	2.94	0.66
6	-	2.33	11.34	1.20	0.43
7	-	3.16	2.81	3.28	1.58
8	-	1.92	1.49	1.11	0.70
9	-	2.33	0.86	2.35	0.87
10	-	5.25	8.57	7.39	4.31
11	-	3.75	5.16	8.01	3.67
12	-	1.67	0.48	0.153	0.99
13	-	3.75	5.26	3.55	6.49
14	-	1.83	0.95	1.16	1.46
15	-	3.58	7.70	0.76	0.72

Farm 1= Owode-Ede, by the road side
Farm 2 = outskirt of Ede
Farm 3= Ilo-Ajegunle
Farm 4= Ila-Orangun, near an abandoned waste depot
Farm 5= Ila-Orangun
Farm 6 = Ido-Ijesa, near fish ponds
Farm 7 = outskirt of Ile-Ife
Farm 8= by the road side, along Ede-road, Ile-Ife
Farm 9 = along Osogbo/Ilie road
Farm 10= Outskirt of Iwo town, near a waste depot
Farm 11= between Telemu and Iwo
Farm 12= along Osogbo/Ikirun road
Farm 13= outskirt of Osogbo town
Farm 14= along Ikirun/Inisha road
Farm 15= outskirt of Osogbo town

Table 4.8: Transfer Factor of Individual Metal from Soil to *Amaranthus hybridus* (mg/kg)

Farm	TFAs	TFCd	TFCu	TFPb	TFZn
1	-	4.44	0.19	0.07	0.77
2	-	2.37	0.35	0.47	0.81
3	-	3.63	0.30	0.68	2.87
4	-	1.96	0.41	0.87	1.10
5	-	0.92	0.15	0.06	0.91
6	-	2.09	0.06	0.38	4.08
7	-	0.73	0.09	0.08	0.56
8	-	3.04	1.30	2.26	2.20
9	-	2.00	0.85	0.24	1.78
10	-	0.34	0.12	0.35	0.35
11	-	1.05	0.18	0.12	0.40
12	-	2.75	1.75	4.28	1.11
13	-	0.78	0.18	0.07	0.31
14	-	0.56	0.75	0.26	0.83
15	-	0.50	0.14	0.01	0.86

Farm 1= Owode-Ede, by the road side
Farm 2 = outskirt of Ede
Farm 3= Ilo-Ajegunle
Farm 4= Ila-Orangun, near an abandoned waste depot
Farm 5= Ila-Orangun
Farm 6 = Ido-Ijesa, near fish ponds

Farm 7 = outskirt of Ile-Ife
Farm 8= by the road side, along Ede-road, Ile-Ife
Farm 9 = along Osogbo/Ilie road
Farm 10= Outskirt of Iwo town, near a waste depot
Farm 11= between Telemu and Iwo
Farm 12= along Osogbo/Ikirun road
Farm 13= outskirt of Osogbo town
Farm 14= along Ikirun/Inisha road
Farm 15= outskirt of Osogbo town

Table 4.9: Transfer Factor of Individual Metal from Soil to *Corchorus olitorious* (mg/kg)

Farm	TFAs	TFCd	TFCu	TFPb	TFZn
1	-	2.11	0.37	0.06	2.63
2	-	1.57	0.60	0.44	0.45
3	-	1.96	0.31	0.34	1.88
4	-	1.22	0.45	0.19	0.19
5	-	1.22	1.65	0.97	0.85
6	-	1.36	0.16	0.08	1.92
7	-	0.40	0.18	0.06	0.47
8	-	1.00	1.33	0.81	0.47
9	-	0.11	0.06	0.32	0.66
10	-	0.92	0.18	0.15	0.19
11	-	0.94	0.30	0.08	0.20
12	-	1.50	2.27	3.86	0.85
13	-	0.67	0.25	0.18	0.13
14	-	0.45	0.26	0.29	0.25
15	-	0.25	0.26	0.19	0.28

Farm 1= Owode-Ede, by the road side
Farm 2 = outskirt of Ede
Farm 3= Ilo-Ajegunle
Farm 4= Ila-Orangun, near an abandoned waste depot
Farm 5= Ila-Orangun
Farm 6 = Ido-Ijesa, near fish ponds

Farm 7 = outskirt of Ile-Ife
Farm 8= by the road side, along Ede-road, Ile-Ife
Farm 9 = along Osogbo/Ilie road
Farm 10= Outskirt of Iwo town, near a waste depot
Farm 11= between Telemu and Iwo
Farm 12= along Osogbo/Ikirun road
Farm 13= outskirt of Osogbo town
Farm 14= along Ikirun/Inisha road
Farm 15= outskirt of Osogbo town

4.8 Estimated Daily Intake of Metals (DIM)

The estimated daily intake of metals through the food chain for adult is given in Tables 4.11 and 4.12. The estimated daily intake of Cd, Cu, Pb and Zn from consumption of Amaranthus ranged from 0.0003-0.001, 0.00021-0.016, 0.002-0.014 and 0.053-0.159 mg/kg/day, respectively and ranged from 0.0002-0.0016, 0.004-0.016, 0.0017-0.0076 and 0.023-0.144 mg/kg/day, respectively from consumption of Corchorus .The highest intake of Cd, Cu, Pb and Zn were from consumption of Amaranthus. The estimated DIM when compared to recommended daily intake/ allowance for heavy metals (USEPA, 2009) was below the recommended daily intake/ allowance for metals studied.

4.9 Potential Health Risk Index (HRI) and Hazard Index (HI)

The potential health risk of heavy metals through consumption of vegetables is presented in Tables 4.13 and 4.14. The HRI for Cd, Cu, Pb and Zn from consumption of Amaranthus ranged from 0.30-1.20, 0.03-0.38, 0.10-4.75 and 0.18-0.86, respectively while it ranged from 0.20-0.90, 0.10-0.43, 0.35-1.68 and 0.08-0.48, respectively for consumption of Corchorus. The result showed high values for Cd and Pb and low values for Cu and Zn. The HRI for Cd and Pb from consumption of Amaranthus was greater than 1 in farms 1, 2, 3, 8 and farms 1, 2, 3, 4, 8, 9, 10, 11, 12, respectively. Health risk index for Pb from consumption of Corchorus was greater than 1 in farms 1, 2, 8, 10, 11, 12 and 13. The calculated hazard index for all the assayed heavy metals in Amaranthus and Corchorus from all the peri-urban farms studied was greater than 1.

Table 4.11: Daily Metals Intake Estimate (mg^{-1} kg^{-1} person^{-1} d^{-1}) from Consumption of *Amaranthus hybridus* in Adults

Farm	As	Cd	Cu	Pb	Zn
1	-	0.0010	0.0080	0.0040	0.1550
2	-	0.0010	0.0100	0.0080	0.2590
3	-	0.0012	0.0110	0.0050	0.1430
4	-	0.0009	0.0150	0.0140	0.1760
5	-	0.0005	0.0010	0.0013	0.0680
6	-	0.0009	0.0054	0.0030	0.2010
7	-	0.0005	0.0021	0.0019	0.1009
8	-	0.0011	0.0160	0.0190	0.1780
9	-	0.0009	0.0060	0.0040	0.1760
10	-	0.0003	0.0085	0.0079	0.1715
11	-	0.0008	0.0070	0.0073	0.1657
12	-	0.0009	0.0069	0.0050	0.1245

13	-	0.0006	0.0078	0.0017	0.1260
14	-	0.0003	0.0057	0.0040	0.1388
15	-	0.0004	0.0070	0.0053	0.0900
RDI	-	0.0640	10.000	0.2400	40.000

RDI-Recommended daily intake/ allowance for heavy metals in mg/day

Farm 1= Owode-Ede, by the road side
Farm 2 = outskirt of Ede
Farm 3= Ilo-Ajegunle
Farm 4= Ila-Orangun, near an abandoned waste depot
Farm 5= Ila-Orangun
Farm 6 = Ido-Ijesa, near fish ponds
Farm 7 = outskirt of Ile-Ife
Farm 8= by the road side, along Ede-road, Ile-Ife
Farm 9 = along Osogbo/Ilie road
Farm 10= Outskirt of Iwo town, near a waste depot
Farm 11= between Telemu and Iwo
Farm 12= along Osogbo/Ikirun road
Farm 13= outskirt of Osogbo town
Farm 14= along Ikirun/Inisha road
Farm 15= outskirt of Osogbo town

Table 4.12: Daily Metals Intake Estimate (mg^{-1} kg^{-1} $person^{-1}$ d^{-1}) from Consumption of *Corchorus olitorious* in Adults

Farm	As	Cd	Cu	Pb	Zn
1	-	0.0006	0.0160	0.0041	0.0920
2	-	0.0008	0.0168	0.0076	0.1440
3	-	0.0006	0.0110	0.0025	0.0920
4	-	0.0004	0.0170	0.0035	0.0290
5	-	0.0007	0.0140	0.0019	0.0640
6	-	0.0006	0.0140	0.0022	0.0940
7	-	0.0004	0.0040	0.0014	0.0843
8	-	0.0004	0.0160	0.0067	0.0380
9	-	0.0004	0.0060	0.0039	0.0660
10	-	0.0009	0.0120	0.0057	1.0939

11	-	0.0008	0.0127	0.0049	0.0820
12	-	0.0005	0.0089	0.0044	0.0960
13	-	0.0005	0.0140	0.0045	0.0990
14	-	0.0002	0.0068	0.0023	0.0420
15	-	0.0002	0.0160	0.0017	0.0230
RDI	-	0.0640	10.000	0.2400	40.000

RDI-Recommended daily intake/ allowance for heavy metals in mg/day

Farm 1= Owode-Ede, by the road side
Farm 2 = outskirt of Ede
Farm 3= Ilo-Ajegunle
Farm 4= Ila-Orangun, near an abandoned waste depot
Farm 5= Ila-Orangun
Farm 6 = Ido-Ijesa, near fish ponds
Farm 7 = outskirt of Ile-Ife
Farm 8= by the road side, along Ede-road, Ile-Ife
Farm 9 = along Osogbo/Ilie road
Farm 10= Outskirt of Iwo town, near a waste depot
Farm 11= between Telemu and Iwo
Farm 12= along Osogbo/Ikirun road
Farm 13= outskirt of Osogbo town
Farm 14= along Ikirun/Inisha road
Farm 15= outskirt of Osogbo town

Table 4.13: Potential Health Risk and Hazard Index of Heavy Metals through Intake of *Amaranthus hybridus* in Adult

Farm	As	Cd	Cu	Pb	Zn	HI
1	-	1.00	0.21	1.00	0.52	2.73
2	-	1.00	0.24	2.03	0.86	4.13
3	-	1.20	0.28	1.25	0.48	3.21
4	-	0.90	0.38	3.50	0.59	5.37
5	-	0.49	0.03	0.33	0.22	1.07
6	-	0.95	0.14	0.75	0.67	2.51
7	-	0.50	0.05	0.48	0.33	1.36

8	-	1.10	0.40	4.75	0.59	6.84
9	-	0.90	0.15	1.00	0.22	2.27
10	-	0.30	0.21	1.98	0.57	3.06
11	-	0.80	0.18	1.83	0.55	3.36
12	-	0.90	0.17	1.25	0.42	2.74
13	-	0.60	0.20	0.43	0.42	1.65
14	-	0.30	0.14	0.10	0.46	1.00
15	-	0.40	0.18	0.13	0.30	1.01

HI = hazard index
Farm 1= Owode-Ede, by the road side
Farm 2 = outskirt of Ede
Farm 3= Ilo-Ajegunle
Farm 4= Ila-Orangun, near an abandoned waste depot
Farm 5= Ila-Orangun
Farm 6 = Ido-Ijesa, near fish ponds
Farm 7 = outskirt of Ile-Ife
Farm 8= by the road side, along Ede-road, Ile-Ife
Farm 9 = along Osogbo/Ilie road
Farm 10= Outskirt of Iwo town, near a waste depot
Farm 11= between Telemu and Iwo
Farm 12= along Osogbo/Ikirun road
Farm 13= outskirt of Osogbo town
Farm 14= along Ikirun/Inisha road
Farm 15= outskirt of Osogbo town

Table 4.14: Potential Health Risk and Hazard Index of Heavy Metals through Intake of *Corchorus olitorius* in Adult

Farm	As	Cd	Cu	Pb	Zn	HI
1	-	0.60	0.40	1.03	0.31	2.30
2	-	0.80	0.42	1.90	0.48	3.60
3	-	0.64	0.28	0.63	0.31	1.86
4	-	0.40	0.43	0.88	0.09	1.80
5	-	0.70	0.35	0.48	0.21	1.74

6	-	0.60	0.35	0.55	0.31	1.81
7	-	0.40	0.10	0.35	0.30	1.15
8	-	0.40	0.40	1.68	0.13	2.61
9	-	0.40	0.15	0.98	0.22	1.75
10	-	0.90	0.30	1.43	0.31	2.94
11	-	0.80	0.32	1.23	0.27	2.62
12	-	0.50	0.22	1.10	0.32	2.14
13	-	0.50	0.28	1.13	0.27	2.24
14	-	0.20	0.17	0.58	0.32	1.09
15	-	0.20	0.40	0.43	0.08	1.11

HI = hazard index

Farm 1= Owode-Ede, by the road side
Farm 2 = outskirt of Ede
Farm 3= Ilo-Ajegunle
Farm 4= Ila-Orangun, near an abandoned waste depot
Farm 5= Ila-Orangun
Farm 6 = Ido-Ijesa, near fish ponds
Farm 7 = outskirt of Ile-Ife
Farm 8= by the road side, along Ede-road, Ile-Ife
Farm 9 = along Osogbo/Ilie road
Farm 10= Outskirt of Iwo town, near a waste depot
Farm 11= between Telemu and Iwo
Farm 12= along Osogbo/Ikirun road
Farm 13= outskirt of Osogbo town
Farm 14= along Ikirun/Inisha road
Farm 15= outskirt of Osogbo town

CHAPTER FIVE

DISCUSSION

The soil pH is one of the most indicative measurements of the general chemical status of soil. The soil pH is typically measured as soil solution pH, it is also an indicator of the proportions of basic and acidic exchangeable ions present in the soil (USDA, 1999). This is because these ions in the soil solution are in equilibrium with the exchangeable ions. The pH affects the mobility of heavy metals in soil. It has been found that soil pH is correlated with the availability of nutrients to plant (Gray *et al.,* 1998). Consequently, as pH decreases, the solubility of metallic elements in the soil increases and they become more readily available to plants (Smith, 1996; Oliver *et al.,* 1998; Salam and Helmke, 1998). Heavy metal mobility decreases with increasing soil pH due to precipitation of hydroxides, carbonates formation of insoluble organic complexes. Heavy metals are generally more mobile at pH < 7 than at pH > 7. The amount of metals mobilized in soil environment is a function of pH, properties of metals, redox condition, soil chemistry, organic matter content and other soil properties (Anem *et al.*, 1998; Kemberly and Williams, 1999; Saure *et al.*, 2000).

Neutral pH would favour availability, mobility and redistribution of metals in the various fractions due to increase solubility of ions in neutral environment (Oviasogie and Ndiokwere, 2008). In this study, the pH ranged between 5.24-7.87 (moderately acidic to slightly alkaline). It was observed that where soil pH was recorded near neutral, low concentration of heavy metals was recorded in vegetables than in soil except for Cd. This high Cd content might be due to vegetables accumulating Cd from manure through foliar absorption. This observation was consistent in farms where inorganic fertilizer and poultry manure were used to maintain soil fertility. This contrasts with the higher Cd uptake by vegetables from soil at low pH of soil (Akinola *et al*, 2008; Alchaerani *et al.*, 2009).

The presence of organic carbon increases the cation exchange capacity of the soil which retains nutrients assimilated by plants (Agbede, 2009). Total organic carbon in the soil of peri-urban farms under investigation ranged from 0.68-6.32%. The total organic carbon were low to high based on classification of soil % OC given by Enwezor *et al.* (1998) in the present study suggesting a possibility of metals retention within the soil. The high amount of organic carbon in some of the peri-urban farms studied (Farms 3 and 8) is suggestive of degradation or presence of degradable and compostable wastes (Munoz *et al*., 1994).

Soil organic matter enhances the usefulness of soils for agricultural purposes. It supplies essential nutrient and has unexcelled capacity to hold water and absorb cations. It also functions as a source of food for soil microbes and thereby helps to enhance and control their activities (Brady, 1999). Organic matter in the soil samples of peri-urban farms studied varied from 1.18 - 10.87 %. Soils of peri-urban farms contain high amount of organic matter which could be as a result of agricultural applications. Ayolagba and Onmigbuta (2001) demonstrated that high organic matter (> 2.0%) in soil is conducive for heavy metals chelation.

Of all the 16 essential plant nutrient elements needed for plant growth, development and reproduction, nitrogen (as nitrate or ammonia) is the most vital and most limiting throughout the world (Agbede, 2009). Animal and man depend on protein manufactured by plants from nitrogen which could be regarded as the key nutrient in plant growth. Nitrogen gas which accounts for about 78% of atmospheric gas has to be converted to two utilizable forms by plants before it can be regarded as useful to plants. These two forms are the cation form, ammonium ion (NH_4^+) and the anion form (NO_3^-). The available NO_3^- is supplied from aerobic decomposition of soil organic matter or added to the soil as chemical nitrogen fertilizers. Nitrate represents the most oxidized form of nitrogen found in natural systems. It is often regarded as an unambiguous indicator of domestic and agricultural pollution. In soil samples, it is formed primarily as a result of oxidation of NH_4^+ to NO_2^- and subsequently, to NO_3^- by nitrication process.

In this study, the percentage nitrogen content of peri-urban farm soils ranged from 0.06-0.54% while nitrate level varied between 20.45-240.52 mg/kg. According to Ideriah, *et al.* (2006), low value of nitrogen content may be attributed to high decomposition and efficient mineralization process. Uwah *et al*. (2009) also reported nitrate level of 311.55-398.65µg/g in soil samples irrigated with waste water obtained from Maiduguri, Nigeria.

Nitrate is formed from fertilizers, decaying plants, manure and other organic residues. It is found in the air, soil, water and food (particularly in vegetables) and is produced naturally within the human body (Walker, 1990; Gangolli *et al*., 1994). It is also used as food additive, mainly as a preservative and antimicrobial agent (Speijer *et al.*, 2003). Due to the increased use of synthetic nitrogen fertilizers and livestock manure in intensive agriculture, vegetables and drinking water may contain higher concentrations of nitrate than in the past. Vegetables are the major sources of the daily intake of nitrate by human beings, supplying about 72 to 94% of the total intake (Ditch, *et al*., 1996). The presence of nitrate in vegetables, and generally in other foods, is a serious threat to man's health. Nitrate per se is relatively non-toxic (Speijer *et al*., 2004; Mesinga *et al.*, 2003) but approximately 5% of all ingested nitrate is converted in saliva and the gastrointestinal tract to the more toxic nitrite (Spiegelholder *et al*., 1979). The only chronic toxic effects of nitrate are those resulting from the nitrite formed by its reduction by bacterial enzymes (Mesinga *et al*., 1976).

Nitrate concentration in vegetables from peri-urban farms ranged from 214.15-1,204.50 mg/kg which is within the permissible limit for nitrate in leafy vegetables (2500-3000 mg/kg) set by WHO/EC (1993). The levels of the anion in the leafy vegetables investigated were in agreement with the fact that leafy vegetables such as spinach contain nitrate at significant levels and that vegetables such as beetroot, lettuce and radish often contain nitrate concentrations above 2500 mg/kg (Maynard *et al.*, 1976). The variation observed in concentrations of nitrate in vegetables of peri-urban farms could be attributed to differences in anthropogenic activities, like different farming practices such as usage of fertilizers, manure and other agrochemicals (Catfineld *et al.*, 1973; Maynard *et al.*,1976) as well as the use of waste water and all kinds of polluted water in irrigating the soils. This could also be attributed to a number of environmental factors such as drought, day light intensity, and soil temperature and soil type (Gangolli *et al.*, 1994; FAO/WHO, 1995). The result obtained in this study is similar to those observed by Nwachukwu *et al.* (2015) who reported nitrate concentration of 2,485µg/g and 938.76 µg/g in *Amaranthus viridi*s and *Vernonia amygdalina* respectively and also to the work of Uwah *et al.* (2009) who also reported nitrate level of 476-8,920 µg/g in vegetables obtained in Maiduguri, Nigeria.

The distribution of metals in soils of peri-urban farms studied was mainly affected by location of the peri-urban farm, prevailing agronomic practices and source of water for irrigation. Peri-urban farms located by the roadside, near waste depots and irrigated with waste water showed the highest level of contamination.

Anthropogenic addition of Cd to soil occurs via short-or long-range atmospheric deposition, addition in fertilizers/manure, municipal sewage wastes (effluents and biosolids), urban composts and industrial sludge (Taylor, 1997). Atmospheric Cd is derived from mining and smelting of non-ferrous metals, the production of iron and steel, combustion of fossil fuels and waste incineration. In fertilizers, Cd is found predominantly in phosphate fertilizers due to its presence as impurity in phosphate rocks. The contribution of atmosphere, fertilizer, sludge, manure or compost to total annual Cd addition to soils varies widely among the countries and regions of the world. (Jensen and Bro-Rasmussen, 1992; Kghlin *et al*., 1996). In less industrialized agricultural regions or countries (e.g Nigeria), atmospheric deposition is minimal. Cadmium is an important toxic heavy metal and the warning of health risks from Cd pollution was issued initially in the 1970s (Taylor, 1997). Increased accumulation of Cd in agricultural soils are known to come from human activities (Taylor, 1997) such as the application of phosphate fertilizers, sewage sludge, waste water and pesticides (Kara *et al*., 2004), from traffic emission and tear and wear of alloyed parts of vehicles.

Concentration of Cd in the soils of various peri-urban farms studied ranged from 0.18-0.63 mg/kg. These values were far lower than the natural limit of 3.0-5.0 mg/kg in soil as given by FAO/WHO (2002), EU (2006), EC (1986) and MAFF (1992). High concentration of Cd in the soil of farm 10 may be due to metals mobility from a nearby waste depot while high level of Cd in the soils of farms 11 and 13 might come from agricultural applications (irrigation water source or the use of inorganic fertilizer as soil amender). The values of Cd concentrations obtained from the soil of peri-urban farms investigated are far below the maximum tolerable levels proposed for agricultural soils. This is in agreement with the findings of Asawalam and Eke (2006), Njoku and Ayoka (2007), Oluyemi *et al*. (2008) and Oyekunle *et al*. (2001) who investigated trace metal concentration and heavy metal pollutants from dump and agricultural soils in Owerri, Ile-Ife and Osogbo, Nigeria.

Copper is added to the diet of some growing animals at levels up to 250 ppm to increase their growth rate and promote feed conversion efficiency. Manure produced by these animals contains high concentrations of Cu. The application of this manure to agricultural soil produces an increase in soil Cu concentration (Mullins *et al*., 1982). In excess, elevated levels of Cu can become toxic to plants, can adversely affect organisms that feed on these plants, and can enter water system through surface run- off and leaching (Gupta and Charles, 1999). Copper can also be introduced into poultry diets involuntarily through contaminated feed stuffs or in much greater proportions as veterinary medicines or growth promoters.

According to Alloway (1990) and Lenntech (2009), copper strongly attaches to organic matter and minerals in soils. As a result, it does not travel very far after release. As a result of the limited mobility, applied Cu tends to accumulate in soil (Slooff *et al*., 1989). In this study, concentration of Cu in the investigated soil samples varied between 2.40-56.17 mg/kg. Soil samples collected from farm 6 and 10 had the highest concentration. Elevated levels of copper in Farm 6 could be traced to the use of Cu as additive in fish pellet (Bolan *et al.,* 2004) which might have leached into the farm while the elevated level of Cu observed in farm 10 could be traced to leaching from a nearby waste depot. The concentrations of Cu in the current study were lower than those recorded in soil samples of Torino (171.00 µg/g) by Biasioli *et al*. (2007) and Guang-dong (576.50 µg/g) by Zhou *et al*. (2007). However, the values obtained are compatible with the values obtained in a Canadian soil in which average Cu concentration was estimated to be 20 mg/kg, with a range between 2 and 100 mg/kg (British Columbia Ministry of Environment, Lands and Parks, 1992).

Lead is ranked as one of the most serious pollutant among the toxic heavy metals, which has been used by mankind for several years because of its wide variety of applications and considered as one of the most toxic metals affecting man, animal and plant (Zude, 2000). Humans are exposed to Pb from various sources and a myriad of pathways like air, water, dust, soil, food, homes and workplace (Zude, 2000). Lead has toxic properties and is found in large amount in many electronic devices (Nordic Council of Ministers, 1995), it is a major constituent of lead acid battery extensively used in car batteries and tyres which can end up in soil through corrosion.

Depending on the source of waste, addition of poultry waste to agricultural soils unconsciously points towards the build-up of heavy metals like Pb in soil (Alloway, 1995). Long term use of these biosolids on agricultural lands often results in the build up of elevated levels of heavy metals such as Pb in soils (Alloway, 1995). In addition, in countries such as Nigeria where there is high demand for food, contaminated arable land is used for crops. Increasing concern for lack of suitable land for agriculture has prompted peri-urban farmers to use contaminated land such as dump sites, major setback on the highways to produce food crops. Thus, peri-urban agriculture practiced widely in developing countries can be of great risk due to proximity of these contaminant sources (Garcia and Millan, 1998). In peri-urban agriculture, wastewater and solid organic wastes are often the main sources of water and fertilizer used to enhance the yields of staple crops and vegetables. This way, municipal or industrial effluents and solid waste often rich in trace metals, contribute significantly to metal loadings in irrigated and waste amended peri-urban soils.

The concentration of lead in the investigated soil samples ranged from 0.70-36.75 mg/kg. In this study, soil samples from farms 1, 10 and 11 had the highest Pb concentration. High Pb concentration observed in farm 1 might be due to past atmospheric deposition derived from combustion of gasoline as a result of the farm's proximity to a highway. High concentration of Pb observed in Farm 10 and 11 could be from irrigation water source or as a result of metals mobility from a nearby waste depot to the farm through leaching and run –off. Lead levels obtained from this study were lower than those detected in British, England and Wales. Alloway (1995) mentioned that the total Pb content of normal British soil ranged from 2 to 300 µg/g. By considering the general range of the Pb content, it appears that the total Pb content in soils of peri-urban farms studied were below the critical concentration of 300 mg/kg (FAO/WHO, 2002) and 400 mg/kg (ICRCL, 1987).

Zinc is included in feed as growth enhancer which may have the ability to cause metal pollution of the soil (Chaney and Oliver, 1996; Summer, 2000). Some animal wastes like livestock, poultry and pig manure created in agriculture are usually supplied to crops and meadows either in the form of solids or semi solids (Summer, 2000). The supply of various biosolids, for example, composts, poultry manure and municipal sewage sludge to land could unconsciously contribute towards the build-up of heavy metals in the soil (Basta *et al.*, 2005). The manure that is created from animals as a result of their diet possesses greater amount of As, Cu, Fe, and Zn and if continually supplied to land, can result in reasonable accumulation of this metal in the longer period of time in the soil.

Zinc is used in break lining because of their heat conducting properties and as such released during mechanical abrasion of vehicles, from engine oil combustion and tyres of motor vehicles which are emitted into the environment as particles during deposition.

In this study, Zn concentration ranged between 30 to 300 mg/kg with farms 10 and 13 having the highest concentrations. High concentration of Zn observed in farm 10 might be due to proximity of the farm to a waste depot from which zinc might have leached into the farm or could also come from irrigation water source. High concentration of Zn observed in farm 13 might come from herbicide application or irrigation water source. Normal concentration of Zn in soil ranges from 1 to 300 mg/kg (FAO/WHO, 2002). Mcgrath (1986) reported that the Zn concentration in the soil of England and Wales ranged from 5 to 3,648 mg/kg. In this study, Zn concentration is lower than this range. Ogundele *et al.* (2005) reported Zn concentration of between 30.8 to 219.23 mg/kg in soils collected along heavy traffic road which is similar to values obtained in this study.

In this study, concentration of Arsenic was recorded below detection limit in almost all soil samples investigated. Heavy metal levels in the control/ reference soil were within the background level range for farming. Concentration of heavy metals in the soils of peri-urban farms were higher compared to heavy metals concentration in the reference soil indicating some degree of pollution in peri-urban farms. The concentration of heavy metals in the soil varied widely between farms as a result of different agronomic practices employed. The concentration of assayed heavy metals in all peri-urban farms studied were within the permissible level for agricultural soil. Even though heavy metal level fell below the critical level, it seems that its persistence in the soil of peri-urban farms may lead to increase uptake by plants.

Heavy metal concentration showed variation among vegetables collected from peri-urban farms. The variation in heavy metal concentrations in the vegetables of the same farm may be ascribed to the differences in their morphology and physiology for heavy metal uptake, exclusion, accumulation and retention (Kumar *et al.*, 2009). Vegetables differ in their ability to accumulate and concentrate metals in their edible parts, differences between them were numerically significant which was well supported from studies carried out by Sharma *et al.* (2006). The uptake and bioaccumulation of heavy metals in vegetables are influenced by many factors such as atmospheric deposition, concentrations of heavy metals in the soil, the nature of soil and degree of maturity of the plants at the time of harvest (Voutsa *et al.*, 1996). Concentration of heavy metals analysed in vegetables also varied from one farm to the other which might be due to differences in farming practices.

In Amaranthus, the concentration of heavy metals ranged between 0.19 -0.83 mg/kg for Cd, 0.85-9.60 mg/kg for Cu, 0.80-11.55 mg/kg for Pb and 32.0 -158.8 for Zn respectively. In Corchorus, heavy metals concentration varied between 0.10-0.58 mg/kg for Cd, 2.18-10.33 mg/kg for Cu, 0.87-4.70 mg/kg for Pb and 14.12-88.50 mg/kg for Zn respectively. The values of As were below detection limit in vegetables studied. The maximum accumulation of Cd was found in Amaranthus (0.49 mg/kg). Cd concentration in amaranthus and Corchorus exceeded the permissible limits prescribed by FAO/WHO and EU (2006) for Cd concentration in leafy vegetables except in Corchorus collected from farms 14 and 15. Cadmium level measured in vegetables of peri-urban farms studied was lower than vegetables (10.37-17.79 mg/kg) from Titagarh West Bengal, India (Gupta *et al*., 2008), vegetables (25 mg/kg) from Turkey (Turkdogan *et al*., 2002) and vegetables grown on irrigated soil in Ilorin (4.8 mg/kg in Amaranthus and 1.5 mg /kg in Corchorus) reported by Ogunkunle *et al.* (2015). More so, this result is close to the finding of Sharma *et al*. (2006) who reported Cd level of 0.50-4.36 mg/kg in Vegetables from Varanasi, India (Turkdogan *et al*., 2002).

Copper concentrations in Amaranthus and Corchorus collected from studied peri-urban farms were below the permissible limits set by FAO/WHO and EU (2006). The mean concentration of Cu in vegetables (4.63 mg/kg for Amaranthus and 7.36 mg/kg for Corchorus) was lower than Cu content in vegetables (61.20 mg/kg) from Zhengzhou city, China (Liu *et al*., 2005) and also lower than the result (15.66-34.49 mg/kg) reported in Titagarh West Bengal, India (Gupta *et al*., 2008). However the variation of Cu concentration in the present study was strongly supported by the findings of Arora *et al*. (2008) who reported Cu level of 5.21-18.2 mg/kg in vegetables and also in good agreement with Cu concentration in leafy vegetables

(8.51-15.5 mg/kg) from Samanta village, Jessor, Bangladesh obtained by Alam *et al*. (2003). Higher Cu concentration was found in Corchorus.

The maximum concentration of lead was exhibited by Amaranthus (3.787 mg /kg). Lead concentrations in vegetables collected from studied peri-urban farms exceeded the permissible limits set by FAO/WHO and EU (2006). Lead content in vegetables was lower than the values reported in Titagarh, West Bengal, (21.59-57.63 mg/kg) and significantly lower than the mean concentration of Pb (409 mg/kg) reported in vegetables from Turkey by Turkdogan *et al.* (2002) but comparable with Pb level reported (0.18-7.75 mg/kg) in China (Liu *et al.*, 2005) and in Varanasi, India (3.09-15.74 mg/kg) by Sharma *et al.*, 2008b).

Vegetables collected from peri-urban farms exceeded the permissible limits set for Zn by FAO/WHO and EU (2006) except in Amaranthus collected from farms 5 and 15 and Corchorus from farms 4, 5, 8, 14 and 15. Highest mean concentration of Zn was found in Amaranthus (86.30 mg/kg) and Corchorus (43.43 mg/kg). Zinc concentration in vegetables from studied peri-urban farms was similar to vegetables (32.01-69.26 mg/kg) from Beijing, China (Liu *et al*., 2005) also from Rajasthan, India (21.1-46.4 mg/kg) reported by Arora *et al.* (2008) and vegetables of Varanasi (59.61-79.46 mg/kg) but substantially lower than Zn concentration in vegetables (1,038-1,872 mg/kg) from Harare, Zimbabwe (Thandi *et al*., 2004).

Vegetables studied were contaminated with heavy metals. Concentration of heavy metals were higher in vegetables of peri-urban farms compared to the reference vegetable sample. Among the heavy metals studied in vegetables, Zn had the highest concentration followed by Cu, Pb and the least was Cd. Similar results were obtained by Abou Audu *et al.* (2011) who studied accumulation of metals (Fe, Zn, Pb and Cd) on crops in Gaza strip. Similar result was also obtained by Zhang *et al*. (2010) who reported that the maximum concentration was Zn, followed by Cu, Cr, Ni, Pb and Cd for two crops (*Cyperus malaccensis* and *Scirpus triqueter*). Amaranthus showed stronger ability to accumulate these metals from soil which is expected due to larger surface area of its leaves, higher transpiration and fast growing rate. This is consistent with the report of Oluwatosin *et al.* (2010). However, Corchorus accumulated more Cu than Amaranthus which revealed potential use of Corchorus as a plant for environmental monitoring and soil remediation of Cu.

The pollution load index is aimed at providing a measure of the degree of the overall contamination of a sampling site. To effectively compare whether the peri-urban farms studied suffer contamination or not, the pollution load index was calculated. The peri-urban farms studied were moderately enriched with Zn and Cd but strongly enriched with Cu and Pb. There was substantial build-up of heavy metals in the soils of peri-urban farms compared to the reference soil. The high pollution load index of studied peri-urban farms suggested input from anthropogenic sources attributed to agricultural applications and irrigation practices.

Transfer factor is the ratio of heavy metal concentration in a plant to the concentration of heavy metal in the soil. It signifies the amount of heavy metals in the soil that ended up in the vegetable crop site (Chamberlain, 1983; Harrison and Chirgawi, 1989; Smith *et al.*, 1996). The soil-to-plant transfer factor is one of the key components of human exposure to metals through the food chain. In order to investigate the human health risk index, it is essential to assess the transfer factor (Ciu *et al*., 2005). When Transfer factor is < 1or = 1, it denotes that the plant only absorbs the heavy metal but does not accumulate and when TF >1, this indicates that plants accumulate the heavy metal.

Transfer factors were found to be higher for Cd and Zn whereas relatively lower values were found in Cu and Pb which varied with sampling site. The high transfer value of Cd and Zn indicate strong bioaccumulation of the metals by vegetables. Similar results were reported by Naser *et al*. (2011) where they found that Zn had the highest transfer factor among other metals and the order was Zn, Fe, Cd, Ni, Co and Pb and they also reported that the high mobility of Zn is a natural occurrence in the soil and the low retention of Zn in the soil than other toxic cations may elevate the Transfer factor of Zn. There existed strong correlation between Cd, Pb and Zn concentrations in the soil of peri-urban farms, Cd, Pb and Zn concentrations in Corchorus including Cu and Zn concentrations in Amaranthus and Corchorus which indicates similar sources of contamination. The general weak correlation between concentration of metals in soils and vegetables which has also been reported (Agbenin *et al*., 2009) indicates that other sources such as foliar absorption might have contributed to heavy metals burden in vegetables. The variations in heavy metal concentrations in vegetables were due to variations in their absorption and accumulation tendency. Soil properties such as pH, organic matter, redox potential, soil texture and clay may also affect heavy metal uptake (Overesch *et al*., 2007).

In this study, the only intake pathway considered for Cd, Cu, Pb and Zn, was assumed to be vegetable consumption. The daily intake of metals values were estimated according to the average vegetable consumption for adults, and compared with the recommended daily intakes/allowance for metals (ATSDR, 1999a; FNB, 2001; Garcia-Rico *et al.*, 2007; USEPA, 2009). The results for the evaluation of DIM for Cd, Cu, Pb and Zn showed that the highest intake of Cd, Cu, Pb and Zn were from the consumption of Amaranthus. The estimated DIM of Cd, Cu, Pb and Zn were below the recommended daily intake/ allowance for metals. Zhuang *et* *al.* (2009) and Sharma *et al*. (2010) also found lower DIM values than tolerable daily intake limits. On the other hand, Sridhara *et al*. (2007) recorded higher DIM values for heavy metals than tolerable daily intake limits.

Cadmium in plant is highly mobile and it is likely to accumulate in both leaves and seeds. In this study, the transfer ratio of Cd between soil and vegetables was high. Strinivas *et al.* (2009) reported that vegetables had more Cadmium than animal products. According to FAO (1999) and USEPA (2009), the recommended daily allowance of Cd is 0.064 mg/day. In this study, vegetables grown in peri-urban farms were below the reported save limit. The DIM values for Cadmium ranged from 0.0003 to 0.001 mg/day and 0.0002-0.0016 mg/day for Amaranthus and Corchorus respectively. Premarathna *et al.* (2011) reported Cd level ranging from 2.30 to 37.80 mg/kg in various vegetables. Okoronko *et al.*, (2006) reported values of between 22.59 mg/kg and 24.47 mg/kg in the vegetables under study. Naser *et al.* (2009) in Bangladesh reported higher level of Cd (53.69 mg/kg) which were more than values obtained in this study in vegetables. There are also evidences of uptake and accumulation in certain plants (ATSDR, 2005a). Cadmium is a toxic metal; it is classified as carcinogenic to human by international agency for research on cancer (IARC, 1993). Intake of too large quantities of Cd by humans from plant grown on Cd rich soils have higher chances of inducing the development of cancers of the lungs, nose, larynx and prostrate as well as inducing respiratory failures, birth defects and heart disorders (Duda-Chodak and Blaszczyk, 2008; Lenntech, 2009). Studies have shown that heavy metals such as Cd can stimulate cell growth in estrogen receptor (ER) positive breast cancer cells (Martin *et al.*, 2003). Indeed, Ionescu *et al*. (2006) found highly significant Cd accumulation in 50 breast cancer tissue biopsies compared to control. In plants, Cd distribute the uptake and transportation of essential micro-nutrients (e.g Ca, Mg, P and K) and water (Nagajyoti *et al.*, 2010).

Vegetables in this study had DIM lower than RDA (10 mg/ day) for Cu (USEPA, 2009). The DIM values for Cu ranged from 0.00021-0.016 mg/day and 0.004-0.016 mg/day for Amaranthus and Corchorus respectively. Similar results have been reported by Uwah *et al*. (2011) who recorded Cu values of between 0.81 mg/kg and 1.75 mg/kg in Spinach and lettuce grown in Nigeria, respectively. Muhammad *et al*. (2008) and Akubugwo *et al*. (2012) also showed similar results in the ranges of 0.25 mg/kg to 0.92 mg/kg and 1.20 to 3.42 mg/kg of Cu respectively in vegetables studied.

Copper is required for the proper functioning of the neurovascular system. It is a component of several enzymes, co-factors and proteins in the body. In particular, Cu functions as an electron transfer intermediate in redox reactions as well as a direct role in maintaining cupro-enzyme activity. Changes in Cu status may have indirect effects on other enzyme status that do not contain Cu. The level of Cu in the body is affected by the level of Zn as it appears to exert an antagonistic effect on Cu status through the induction of metallothionein synthesis by Zn in mucosal cells in the intestine. Methalonine bound Cu is not available for transport into the circulation and is eventually lost in faeces (Gyorffy and Chan, 1992; Barone *et al.,* 1998; Zahir *et al.,* 2009). Lower Cu uptake in human consumption can cause a number of symptoms which include growth retardation, Skin ailments and gastro-intestinal disorders. Copper deficiency impinges on Fe metabolism, causing anaemia that does not respond to Fe supplementation. Cu deficiency also exerts an effect on iodine metabolism resulting in hypothyroidism, at least in animal models (Michael *et al*., 2009).

Lead accumulation in many plants can exceed several hundred times the threshold of maximum level permissible for human (Wierzbicka, 1995). In this study, estimated DIM ranged from 0.002-0.014 mg/day and 0.0017-0.0076 mg/day for Amaranthus and Corchorus respectively. Naser *et al*. (2009), Orisakwe *et al*. (2012) and Akubugwo *et al*. (2012) reported Pb levels in the vegetables in ranges similar to those of this study. They reported values of between 0.35 to 3.89 mg/kg, 0.49 to 1.97 mg/kg and 0.13 to 0.73 mg/kg, respectively. Other studies showed that Pb metal level in spinach, coriander, lettuce, radish, cabbage and cauliflower were 2.251, 2.652, 2.411, 2.035, 1.921 and 1.331 mg//kg, respectively (Muhammad *et al*., 2008). According to the maximum allowable limit for Pb in vegetables which is 0.243mg/day, vegetables grown in peri-urban farms were lower than the limit.

Lead has no beneficial biological function and is known to accumulate in the body (Zurera-Cosano *et al*., 1984; Ellen *et al*., 1990; Yargholi and Azimi, 2008). Lead exposure can cause adverse health effects, especially in young children and pregnant women since Pb is a neurotoxin that permanently interrupts normal brain development. It also accumulates in the skeleton and its mobilization from bones during pregnancy and lactation causes exposure to fetuses and breastfed infants (WHO, 2004; ATSDR, 2007). Lead on a cellular and molecular level may enhance carcinogenic events involved in DNA damage, DNA repair and regulation of tumor suppressor and promoter genes (Silbegeld, 2003).

The daily metal intake of Zn was found to be below the recommended RDA of 60 and 40 mg/day by (FAO/WHO, 1999) and USEPA (2009), respectively. In this study, the estimated DIM for Zn ranged from 0.053-0.259 mg/day and 0.023-0.144 mg/day for amaranthus and corchorus respectively. Result from this study was higher compared with studies done by Akubugwo *et al.* (2012) on *Amaranthus hybridus* who reported values of Zn to be in the range of 1.06 to 2.88 mg/kg. Muhammad *et al*. (2008) also reported the amount of Zn in leafy vegetables samples as 0.461 (spinach), 0.705 (coriander), 0.743 (lettuce), 1.893 (raddish) 0.777 (cabbage) and 0.678 (cauliflower) mg/kg, respectively.

Zinc is required by protein kinases to participate in signal transduction processes and is to be a stimulator of transducting factors responsible for regulating gene expression. Zinc plays an important role in the immune system and is an anti-oxidant *in vivo* (Demirenzen and Aksoy, 2006; Michael *et al*., 2009; Stranchan, 2010). Zinc deficiency can disturb Zn maintenance in human body. The clinical manifestations of Zn deficiency in human are growth retardation, neuropsychiatry disturbances, dermatitis, alopecia, diarrhea, increased susceptibility to infections and loss of appetite (Dermirezen and Aksoy, 2006; Michael, 2009). High concentration of Zn in vegetables may cause vomiting, renal damage, cramps e.t.c.

In order to assess the health risk of any chemical pollutant, it is essential to estimate the level of exposure by quantifying the routes of exposure of a pollutant to the target organisms. There are various possible exposure pathways of pollutant to humans but the food chain is one of the most important pathways. Vegetable consumption has been identified as one of the major pathways of human exposure to toxic heavy metals accumulated in vegetables. The health risk index for Cd, Cu, Pb and Zn from consumption of Amaranthus ranged from 0.30-1.20, 0.03-0.38, 0.10-4.75 and 0.18-0.86, respectively while it ranged from 0.20-0.90, 0.10-0.43, 0.35-1.68 and 0.08-0.48, respectively for consumption of Corchorus. The result showed high values for Cd and Pb but low values for Cu and Zn for both Amaranthus and Corchorus. Cadmium and Pb are non essential elements contributing to health hazards even at extremely low concentrations. Ikeda *et al.* (2000) and Zhuang *et al*. (2009) reported HRI values for Cd and Pb that are above permissible limits in vegetables and cereals. The values of Cd and Pb were high possibly because As, Cd and Pb were considered as the most significant heavy metals affecting vegetable crops (Anthony and Balwart, 2007).

Considering individual heavy metal, the health risk index is in the order Pb > Cd > Zn > Cu but when considering vegetables type, the health risk index was Amaranthus > Corchorus. The calculated HRI for Cd and Pb from consumption of Amaranthus was greater than 1 in farms 1, 2, 3, 8 and farms 1, 2, 3, 4, 8, 9, 10, 11, 12, respectively. Health risk index for Pb from consumption of Corchorus was greater than 1 in farms 1, 2, 8, 10, 11, 12 and 13 which means that inhabitants around farms 1, 2, 3, and 8 are at significant risk of Cd toxicity from consumption of Amaranthus while inhabitants around farms 1, 2, 3, 4, 8, 9, 10, 11,12, 13 are exposed to risk of Pb toxicity from consumption of either Amaranthus or Corchorus. The calculated hazard index for all the assayed heavy metals in Amaranthus and Corchorus of all the peri-urban farms studied was greater than 1. The findings of this study regarding HI suggest that vegetables grown in selected peri-urban farms are not safe for consumption.

This assessment was only to measure the intake of toxic heavy metals through vegetable consumption. Human beings are also exposed to heavy metals through other pathways such as consumption of contaminated food crops, eating of sick animals, milk etc (Wang *et al*., 2005; Khan *et al*., 2008; Sipter *et al*., 2008). Moreover, there may be other sources of metal exposures such as dust inhalation, dermal contact (Grasmuck and Scholz, 2005; Hellstrom, 2007) which were not included in this study.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

In this study, vegetables and soil samples collected from selected peri-urban farms around Osun State were analysed for their nitrate, As, Cd, Cu, Pb and Zn concentration. A control, set up in the greenhouse which served as the reference soil and vegetable samples were also subjected to similar treatment. Nitrate concentration in vegetables were within the published permissible level of nitrate in some vegetables and fruits. Investigated Heavy metals concentration in the soils of studied peri-urban farms were within the background range for farming set by FAO/WHO (2002) and EU (2006). The results obtained from vegetables analysis for Cd, Cu, Pb and Zn indicate appreciable levels of these metals in all the samples. Arsenic concentration was below detection limit in soils and vegetables collected from peri-urban farms. Variation in heavy metals concentration in soil and vegetables from peri-urban farms studied reflect the differences in farming practices.

Vegetables exhibited heavy metal concentration in higher ranges. Average metal concentration was higher in Amaranthus compared to Corchorus which suggest that Amaranthus has relatively higher bioaccumulation capacity compared to Corchorus and could be a good indicator of environmental pollution. However, Corchorus showed higher retention capacity for Cu revealing potential use of Corchorus as a plant for environmental monitoring and soil remediation of Cu.

The overall degree of pollution (PLI) indicates strong signs of pollution by the measured metals. Pollution load index showed substantial build-up of heavy metals in peri-urban farm soils compared to reference soil. There were indications that sources of these metals were mainly anthropogenic which may include traffic emissions and agricultural input.

The potential health risk posed by vegetables contaminated with heavy metals was determined using the transfer factor (TF), extrapolation of daily intake of metals (DIM), health risk index (HRI) and hazard index (HI). The variability of heavy metals transfer factor was shown to be inherently strong for Cd and Zn but mild for Cu and Pb. Part of that variability could be explained by the effect of environment on biological functions responsible for the uptake, translocation and accumulation of heavy metals. This study also showed that vegetables under study may pose health risk to consumers as they were found to be deficient of essential metals such as Cu and Zn. on the other hand they were found to have higher than allowable level of metals such as Cd and Pb which are toxic metals. Also the hazard index of heavy metals in all the peri-urban farms studied was > 1 indicating relative presence of health risks associated with ingestion of contaminated vegetables.

6.2 Recommendations

In order to decrease soil and plant contamination resulting from agricultural practices, the following are therefore recommended:

5. Regular monitoring of nitrate and heavy metals in soil and vegetables should be performed in order to prevent excessive build up in the food chain.
6. An intensive sampling is required for the quantification of the result throughout the country.
7. Government of Nigeria should task scientist to establish permissible limits for nitrate and heavy metals in soils and food crops.
8. Caution must be exercised in consumption of *Amaranthus hybridus* due to its ability to bio-accumulate heavy metals above the recommended safe limits which is a critical driver for high dietary exposure to metals consequently posing risk to human health.

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APPENDIX I

QUESTIONNAIRE

Personal Questionnaire for Assessing Peri-urban Farming Activities in Selected Areas

S/N	ITEMS	RESPONSE
1	How do you source for seeds?	
2	What is the source of water for irrigation?	
3	How do you maintain soil fertility?	
4	Is there any agrochemical input?	

5	What are the vegetables grown on the farm?	
6	What is the age of vegetables at harvest?	
7	How productive is the system in terms of harvest?	

APPENDIX II

Table 1: Analysis of Variance for Comparison of Cd Concentration in Peri-urban Farm Soils and Reference Soil

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
FARM	15	0.796	0.053	9.58	<.0001
REP	2	0.032	0.016	2.86	0.073

Table 2: Analysis of Variance for Comparison of Cd Concentration in Peri-urban Farm Amaranthus and Reference Amaranthus

Source	DF	Sum Of Square	Mean Square	F Value	Pr > F
FARM	15	2.859	0.191	2.26	0.028
REP	2	0.163	0.082	0.97	0.392

Table 3: Analysis of Variance for Comparison of Cd Concentration in Peri-urban Farm Corchorus and Reference Corchorus

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
FARM	15	1.161	0.077	21.77	<.0001
REP	2	0.001	0.0006	0.18	0.838

Table 4: Analysis of Variance for Comparison of Cu Concentration in Peri-urban Farm Soils and Reference Soil

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
FARM	15	10964	730.9	37718	<.0001
REP	2	0.043	0.021	1.1	0.345

Table 5: Analysis of Variance for Comparison of Cu Concentration in Peri-urban Farm Amaranthus and Reference Amaranthus

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
FARM	15	257.4	17.16	579.9	<.0001
REP	2	0.019	0.009	0.32	0.729

Table 6: Analysis of Variance for Comparison of Cu Concentration in Peri-urban Farm Corchorus and Reference Corchorus

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
FARM	15	445.2	29.68	1158	<.0001
REP	2	0.041	0.02	0.79	0.462

Table 7: **Analysis of Variance for Comparison of Pb Concentration in Peri-urban Farm Soil and Reference Soil**

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
FARM	15	6439	429.3	152.7	<.0001
REP	2	1.095	0.547	0.19	0.824

Table 8: Analysis of Variance for Comparison of Pb Concentration in Peri-urban Farm Amaranthus and Reference Amaranthus

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
FARM	15	353.5	23.57	244.3	<.0001
REP	2	0.191	0.095	0.99	0.383

Table 9: Analysis of Variance for Comparison of Pb Concentration in Peri-urban Farm Corchorus and Reference Corchorus

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
FARM	15	79.84	5.323	111.1	<.0001
REP	2	0.109	0.054	1.14	0.335

Table 10: Analysis of Variance for Comparison of Zn Concentration in Peri-urban Farm Soil and Reference Soil

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
FARM	15	0.00003	23131	805.6	<.0001
REP	2	71.26	35.63	1.24	0.304

Table 11: Analysis of Variance for Comparison of Zn Concentration in Peri-urban Farm Amaranthus and Reference Amaranthus

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
FARM	15	48652	3243	369.2	<.0001
REP	2	21.47	10.74	1.22	0.309

Table 12: Analysis of Variance for Comparison of Zn Concentration in Peri-urban Farm Corchorus and Reference Corchorus

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
FARM	15	23449	1563	451.7	<.0001
REP	2	5.327	2.664	0.77	0.472