

HEAVY METAL CONCENTRATION IN FLUTED PUMPKIN
(*TELFAIRIA OCCIDENTALIS*) AND HEALTH RISK
ASSESSMENT IN OBIO/AKPOR, RIVERS STATE, NIGERIA

BY

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CERTIFICATION

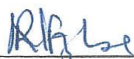
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Dedication

I dedicate this research work to the Almighty God for His grace and mercy towards me.

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Abstract

Heavy metals are non biodegradables and are inimical to human health. This research work was therefore carried out to establish heavy metal concentration in fluted pumpkin (*Telfairia occidentalis*) in Obio/Akpor, Rivers state Southern Nigeria. *Vegetable and soil samples* were collected from ten different locations, taken to the laboratory and analyzed using standard methods. Six heavy metals (Pb, Cr, Cd, Zn, Cu and Fe) discovered in the vegetables were analyzed using an Atomic Absorption Spectrophotometer (AAS). Consequently, human health risk levels associated with the consumption of these metals were also determined. The mean heavy metals concentration in the vegetable ranged as follows: Zn(7.56-36.77mg/kg), Fe(261.42-416.06mg/kg), Pb(1.00-2.01mg/kg), Cd(0.35-0.55mg/kg), Cu(4.62mg/kg) and Cr(1.49mg/kg), The concentrations of all metals were generally below the permissible limits of WHO/FAO in vegetables except for Pb, Cd and Cr in some locations. However, statistical analysis of levels of the studied metals in *T. occidentalis* showed significant differences ($p>0.05$). The heavy metal concentration was in the order: Fe>Zn>Pb>Cu>Cr>Cd. In terms of location, Iriebe showed the highest heavy metal concentration; followed by Oginigba and Rumuodara, which was the control showed the least. To assess the health risk of the inhabitants of Obio/Akpor due to heavy metal intake from *T. occidentalis* consumption, the target hazard quotient (THQ), daily intake of metals (DIM), health risk index (HRI) and hazard index (HI) were calculated. The daily intake of Cu (0.393) and Zn (1.978) were lower than the recommended daily intake level of metals and the tolerable upper intake level (UL). But the DIM of Pb (0.128), Cd (0.038) and Fe (27.488) exceeded the recommended daily intake level however, fall within the tolerable upper intake level. Cr (0.127) was lower than the recommended oral reference dose (RfD) of 1.5mg/kg. The THQ of all heavy metals in this study was less than 1; therefore, it does not pose health risk concern. However, The HRI and HI values show that the population may be at risk of heavy metal contamination. Since *T. occidentalis* consumption is only one out of the many popular vegetables planted in this area, if other vegetable consumption as well as other routes of heavy metals exposure is considered, the potential health risks for the inhabitants might be higher than in this study. Therefore, there is need for continuous monitoring of heavy metals contamination because of its toxicity effect.

Key words: *Heavy metals, T. occidentalis, Daily Intake of Metals (DIM), Health Risk Index, Target Hazard Quotient (THQ), Health Risk Index (HRI), Hazard (Index)*

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Fluted pumpkin (*Telfairia occidentalis*) belongs to the family Cucurbitaceae. It is an edible vegetable well known in West Africa especially, Nigeria. It is said to be indigenous to the Southern part of Nigeria (Akoroda, 1990). Fluted pumpkin has become a household name in the South-South or Niger Delta region of Nigeria. It is used in the preparation of the popular edikang-ikong soup among the Ibibio/efik people. Also, it is used in the popular ogu soup among the igbo people. Apart from its palatable taste when consumed in delicacies, fluted pumpkin is widely known for its nutritional, medicinal and economic values. It is cultivated across low land areas rich in mineral elements. The plant is tolerant to drought and poor soil. Sandy loam soil is preferable in its cultivation and it can be planted and harvested in about thirty days. Fluted pumpkin (*Telfairia occidentalis*) can be subjected to repeat harvesting of over eight months after the first harvest. Perennial traits have also been observed in fluted pumpkin (*Telfairia occidentalis*); that is, the subsisting underground “tuber” could sprout and produce new plant after the first generation fruits have been harvested. Fluted pumpkin (*Telfairia occidentalis*) is majorly a dioecious flowering plant, that is, it produces separate male and female parts on different plants, with very few documented cases of monoecious (both male and female parts on the same plants) flowering.

Nutritionally, fluted pumpkin (*Telfairia occidentalis*) is rich in minerals such as iron, sodium, potassium, and phosphorus. They are also rich in vitamins such as; ascorbic acid, thiamine, nicotinamide and riboflavin. Minerals and vitamins play active roles in its body growth and maintenance. Apart from vitamins and minerals, fluted pumpkin (*Telfairia occidentalis*) also contain carbohydrate, proteins and fats, which means they can be included in dishes to make a well balanced diet. Medicinally, fluted pumpkin (*Telfairia occidentalis*) is used in the prevention and treatment of many diseases. Since it has anti-diabetic effect; it is used in the treatment of diabetes mellitus. It is widely known in the treatment of anemia because of the presence of iron and other important minerals in it that contribute in boosting of blood in the body. This vegetable is also used in the prevention and treatment of osteoporosis because of the presence of calcium which helps in bone calcification. The leaf have been found effective in treating convulsion in children; when sliced and mixed with coconut water and a small amount of salt (Kayode & Kayode, 2011). Fluted pumpkin (*Telfairia occidentalis*) is also known to contain phytochemicals like phenol. Phenol and its chemical derivatives are essential in the production of pharmaceutical drugs (Oboh and Akindahunsi, 2004). Economically, because of the numerous health benefits of fluted pumpkin (*Telfairia occidentalis*) it is of high demand all over Nigeria. And since it can be planted and harvested within a short period, affordable and the plant is tolerant to drought and poor soil, it is a means of quick cash to its growers.

Heavy metals such as Copper (Cu), Cadmium (Cd), Zinc (Zn), Lead (Pb), Chromium (Cr) and Iron (Fe) are commonly found on contaminated sites (Nwachukwu, Feng & Alinnor 2010). Heavy metals such as Cu, Zn and Fe are essential micronutrients for plant metabolism, but when in excess they become toxic to plants. Both essential and non-essential micronutrients when in excess in the human body pose adverse effect on human health. Bioaccumulation of heavy metals when humans consume contaminated vegetables is a real possibility with attendant health challenges (Inioti, Mansour, Bhat, Vicente and Gómez-López, 2012). Most heavy metals can be very harmful since they are non-biodegradable; they have long biological half lives and potential to accumulate in different body parts. Some of the heavy metals can be very toxic even at low concentrations because there is no good mechanism for their excretion from the body (Otitoju, Otitoju, Iyeghe and Onwurah, 2014).

It is a general consensus among many researchers that vegetables planted in areas of serious anthropogenic activities can be contaminated with heavy metals (Odiaka & Odiaka, 2011; Ikhajiagbe, Odigie, Oghogho, and Omoregbee, 2013; Echem, 2014; Okon, Sunday and Peter, 2015; Kalagbor, Echem, Omeokwe, Omelebele, Omereji, *et al*, 2017). And it has been established that the major cause of heavy metal contamination of vegetables can be due to uptake of heavy metals from polluted soil by vegetables (Nwoko, Emenyonu and Umejuru, 2014) and exposure of vegetables to air contaminated with heavy metals (Nwoko & Mgbeahurike, 2011; Zhang, Yan, Zeng, Zhang, Shrestha, Devkota, and Yao, 2012; Echem and Kabari, 2012; Okon, Sunday &

Peter, 2015). Fluted pumpkin (*Telfairia occidentalis*) contaminations by heavy metals have been reported (Echem, 2014; Okon *et al.* 2015). Other vegetable contaminants due to exposure to polluted air include: sulphur and nitrogen oxides, carbon (II) oxide and soot particles (Agbaire & Esiefarienne, 2009; Njoku-Tony, Ihejirika, Ebe, Nwachukwu, Egbuawa, *et al* 2017). Studies have shown that uncontrolled urban and industrial developments have contributed to high levels of heavy metals in the environment. Ali and Al-Qahtani (2012), have reported that leafy vegetables accumulate higher metals concentration than other food crops.

Obio/Akpor is one of the major urban areas in the Niger Delta region in Nigeria with heavy industrial activities going on. The area is also characterized with serious vehicular traffic. Since fluted pumpkin (*Telfairia occidentalis*) is one of the commonly consumed vegetable in this area, they have been an indiscriminate cultivation of this many purpose vegetable. Hence, this study is aimed at investigating the presence and concentration of these heavy metals on fluted pumpkin (*Telfairia occidentalis*) and also assesses the risk of human consumption of these heavy metals via this vegetable to recommend ways to reduce the risk of heavy metal poisoning.

1.2 Problem Statement

Heavy metals such as Lead(Pb), Copper(Cu), Zinc(Zn), Iron(Fe), Cadmium(Cd) and Chromium(Cr) contaminations in soils and vegetables around urban areas with heavy traffic and industrial activities as well as other anthropogenic activities have been widely

reported in literatures. Also, there are numerous reports on the public health implications of consuming vegetables contaminated with heavy metals (Sharma, Agrawal and Marshal, 2008; Nwachukwu, Feng and Alinnor, 2010; Echem, 2014).

Obio/Akpor is located in the Niger Delta region of Nigeria. It is one of the major centres of economic activities in Nigeria; there are a lot of industries located in this area, example is the popular Trans Amadi industrial area which is located within this area. Obio/Akpor is generally a lowland area. The area experiences high rainfall; hence, the soil is usually sandy loam; which favors the cultivation of fluted pumpkin. Also, the area is known to experience flooding and leaching, which can aid the transport of these heavy metals from one location to the other (Awokunmi, Asaolu and Ipinmoroti, 2010; Eludoyin, Wokocha and Ayoalagha, 2011).

Fluted pumpkin (*Telfairia occidentalis*) is one of the most widely consumed vegetables in Nigeria especially in the Niger Delta region. This is mainly due to its widely known nutritional and health benefits especially, in boosting blood levels in the body. Also, since Fluted pumpkin (*Telfairia occidentalis*) can be planted and harvested within a short period of time of about thirty days and the Niger Delta soil promotes its cultivation, it is of great commercial benefit to farmers. Hence, they have been indiscriminate cultivation of Fluted pumpkin (*Telfairia occidentalis*) on soils in this area.

Therefore, there is need to assess the heavy metal content of Fluted pumpkin (*Telfairia occidentalis*) leaves and the human health risk assessment in this area for adequate

measures to be taken to control the release of these heavy metals in the environment as a means of promoting a sustainable environment.

1.3 Aim and Objectives

The aim of this study was to assess the heavy metal concentration in fluted pumpkin (*Telfairia occidentalis*) and the human health risk assessment of these metals.

The above aim was achieved through the following objectives:

- i. to determine the heavy metal concentration in fluted pumpkin (*Telfairia occidentalis*),
- ii. to assess if the heavy metal concentration was within safe limits when consumed by humans,
- iii. to assess the human health risks of the consumers of contaminated vegetable.

1.4 Justification of study

This study will help bring to light the effects of anthropogenic activities in the release of heavy metals into the environment and the health implications of these heavy metals on humans when vegetables planted on contaminated soil as well as vegetables exposed to polluted air are consumed.

1.5 Scope of study

This study investigated the presence and concentration of heavy metals such as Lead (Pb), Copper (Cu), Zinc (Zn), Iron (Fe), Cadmium (Cd), and Chromium (Cd) in fluted pumpkin (*Telfairia occidentalis*). The study also assessed the human health implication of these heavy metals when consumed.

CHAPTER TWO

2.0 LITTERATURE REVIEW

2.1 General description of fluted pumpkin (*Telfairia occidentalis*)

Fluted pumpkin (*Telfairia occidentalis*) is a tropical vine plant indigenous to West Africa especially the rain forest area of Nigeria. It is an herbaceous vascular plant with dicotyledons. It is a vegetable of great importance in Nigeria. It is called "ugu" in Igbo, "iroko" or "apiroko" in Yoruba, "nkong ubong" in Efik/Ibibio, "umee" in Urhobo, and "umeke" in Edo. Fluted pumpkin is rarely found wild, it is mostly cultivated. Parts of the plant consumed are leaves and dry or fresh seeds. Fluted pumpkin can produce two to five fruits per plant (the fruits are usually pale green in colour) and each fruit can produce thirty to seventy seeds which are usually black or brown-red in colour (Chukwurah, 2010).

Scientific Classification

Kingdom:	Plantae
Phylum:	Tracheophyta
Class:	Magnoliopsida
Order:	Cucurbitales
Family:	Cucurbitaceae
Genus:	Telfairia
Species:	<i>Telfairia occidentalis</i>
Binomial name:	<i>Telfairia occidentalis</i> Hook. F. (www.wikipedia.com)

2.1.1 Cultivation of Fluted Pumpkin (*Telfairia Occidentalis*)

Cultivation of fluted pumpkin requires soil that is well drained with sandy loam texture, neutral in PH and rich in organic matter. Fluted pumpkin is a spermatophyte; it is cultivated by planting its mature seeds; the immature seeds are excluded because they contain no cotyledons. Fluted pumpkin produces recalcitrant seeds that cannot be stored for long therefore; its seeds must be processed for planting immediately after opening the pod (fruit). It is a dioecious flowering plant (magnoliophyte) where the female plants are often stronger with thicker stems and broader leaves than the male plants. The female plants produce higher leaf yield than the male plant during harvest (Torimiro, 2018).



Plate 2.1. Fluted Pumpkin (*Telfairia occidentalis*)



Plate 2.2. Fluted Pumpkin farm close to a construction site, Rumuokwurushi

2.1.2 Importance of Fluted Pumpkin (*Telfairia Occidentalis*)

Medicinally, fluted pumpkin leaf is rich in antioxidants such as, ascorbic acid, tocopherols and flavanoids. Antioxidants fight cellular damage and help reduce the risk of cancer, heart disease, Alzheimer's disease, heart attack, atherosclerosis and arthritis (Torimiro, 2018). Researchers have validated fluted pumpkin leaf to have properties that can prevent cancer (Chukwuma, 2015). The leaf of fluted pumpkin is also rich in vitamin such as, vitamin A, B-group (niacin, thiamin, riboflavin and folic acid), C and E. It is also rich in mineral elements such as, potassium; sodium and calcium therefore, contribute to body growth and human health. Fluted pumpkin also contains dietary fiber which is found in plants food only. Dietary fiber helps the digestive system to run smoothly and also help to scour cholesterol from the arteries, hence, reducing the risk of heart disease.

Nutritionally, the fresh fluted pumpkin leaf is consumed as vegetable. It can be used in the preparation of soup and other dishes. The young immature seed of fluted pumpkin can be boiled and eaten. Pumpkin seeds are good for breastfeeding mothers since they are rich in vitamins and minerals, and are naturally rich in phytosterols; which are chemicals, proven to reduce cholesterol. Pumpkin seeds are also known to contain the amino acid tryptophan that produces serotonin which is good in enhancing mood (Schippers, 2002).

Industrially, fluted pumpkin seed contain oil which is a source of raw material for vegetable oil industries. The oil from the seeds can also be used in the production of cosmetics and soaps; and marmalade manufacturing (Chukwurah, 2010).

Ecologically, since fluted pumpkin is a creeping vegetative shrub that spread low across the ground with long twisting tendrils, it can protect the surface of the soil against direct effect of sunlight and rainfall (Chukwurah, 2010). The leaf and seed can serve as food for animals at different trophic level.

2.2 General description of heavy metals

Heavy metals are naturally occurring metallic chemical elements that have relatively high density and high atomic weight. They are not biodegradable. As trace elements (example, copper, zinc and iron), they play vital roles in the metabolism of plants and animals since they are involved in a lot of physiological and biochemical reactions in the body; but at high concentrations they can be toxic to both plants and animals.

They can enter the human body through solid food (directly or through the food chain), water (example, drinking water from contaminated lead pipes) or air (example, exposure to high ambient air concentrations near emission sources) (Lentech, 2018; Tsafe, Hassan, Sahabi, Alhassan, and Bala, 2012). Environmental pollution can also occur through soil erosion and leaching of heavy metals. Other means of heavy metal pollution include metal corrosion, metal evaporation from water resources to soil and ground water, as well as atmospheric deposition. For example, heavy metals can enter a water supply by industrial and consumer waste, or even from acidic rain breaking down soils and releasing heavy metals into streams, lakes, rivers, and groundwater (Lenntech, 2018). Due to the wide use of heavy metals in several industries including, pharmaceuticals, agriculture, oil and gas, construction, mining and domestic, they have been a rise in

human exposure to heavy metals in recent times. There is barely a sector of the economy that does not use heavy metals. Since heavy metals can be toxic even at very low concentrations, it has been a subject of great concern to public human health and the ecosystem (Lenntech, 2018; Tchounwou, Yedjou, Patlolla and Sutton, 2012).

2.2.1 Heavy Metals and Adverse Health Effects

Heavy metals are dangerous because they tend to bioaccumulate. Bioaccumulation means an increase in the concentration of a chemical in a biological organism over time, compared to the chemical's concentration in the environment. Compounds accumulate in living things any time they are taken up and stored faster than they are broken down (metabolized) or excreted (Lenntech, 2018). Heavy metal toxicity depends upon the absorbed dose, the route of exposure and duration of exposure, i.e. acute or chronic (Jaishankar, Tseten, Anbalagan, Mathew and Beeregowda, 2014).

2.2.1.1 Lead

Lead is a bluish-grey metal occurring naturally in small amounts in the earth's crust. Lead has a lot of applications; it is used in the production of lead-acid batteries used in automobiles. It is also used in some types of ammunition, fishing weights, pipes, solder, manufacture of sheeting and as filler in the automobile body industry. Lead pigments are added to glass to prevent radiation exposure from television and computer screens.

Although lead occurs naturally in the environment, anthropogenic activities such as fossil fuel burning, manufacturing and mining have contributed to its increase in the environment (Saskatchewan, 2010).

For instance, lead fumes can be released when waste oil, coloured newsprint, battery casings or wood covered with lead paint are burned. Lead can enter water supply from lead solder in plumbing, lead service connections or lead pipes in homes. Lead in soil can increase due to air borne lead emissions such as automobile emissions, smelters or refineries, or from erosion of lead-bearing rocks, or from lead-based paints, and may be carried indoors as dust (Tchounwou, Yedjou, Patlolla and Sutton 2012). Human exposure to lead occurs mainly through inhalation of lead-contaminated dust particles or aerosols, and ingestion of lead-contaminated food and water (Saskatchewan, 2010).

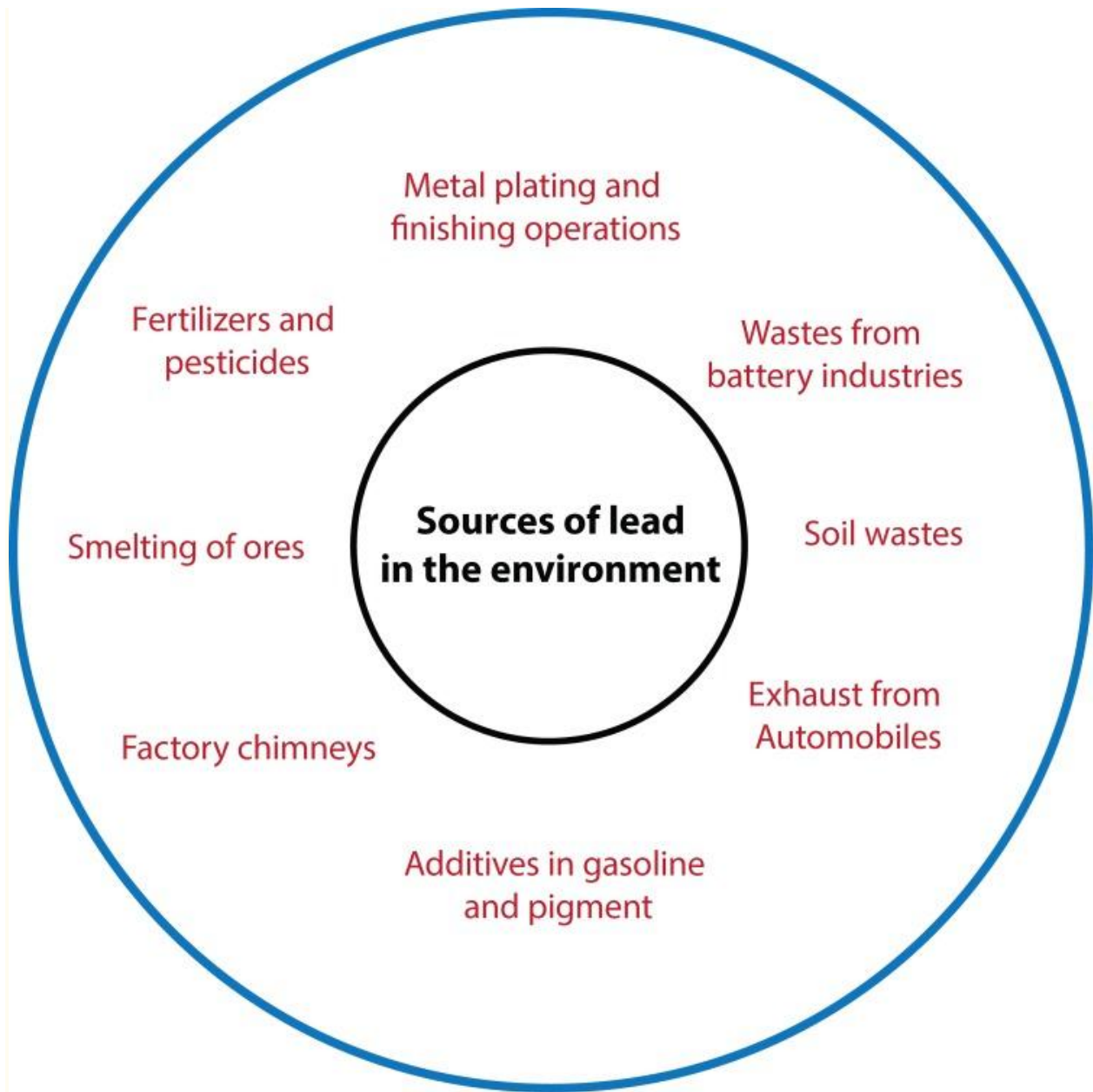


Fig 2.1. Various sources of lead pollution in the environment (Adapted from Sharma & Dubey, 2005). In: Jaishankar, *et al.*, 2014).

2.2.1.1.1 Effects of Lead on Human Health

Lead can affect almost every organ of the human body. Children and pregnant women are the most vulnerable. Even at low concentrations, lead in the blood of children can result in lower IQ and hyperactivity, hearing problems, behaviour and learning problems, slowed growth and anemia. In pregnant women, lead can cross the placental mother barrier exposing the fetus to lead and this can result in serious complications such as premature birth or reduced growth of the fetus. Generally, human exposure to high concentration of lead can lead to decreased kidney function, reproductive problems in male and female, cardiovascular effects, increased blood pressure and hypertension (USEPA, 2017; Brochin, Leone, Phillips, Shepard, Zisa, *et al.*, 2008).

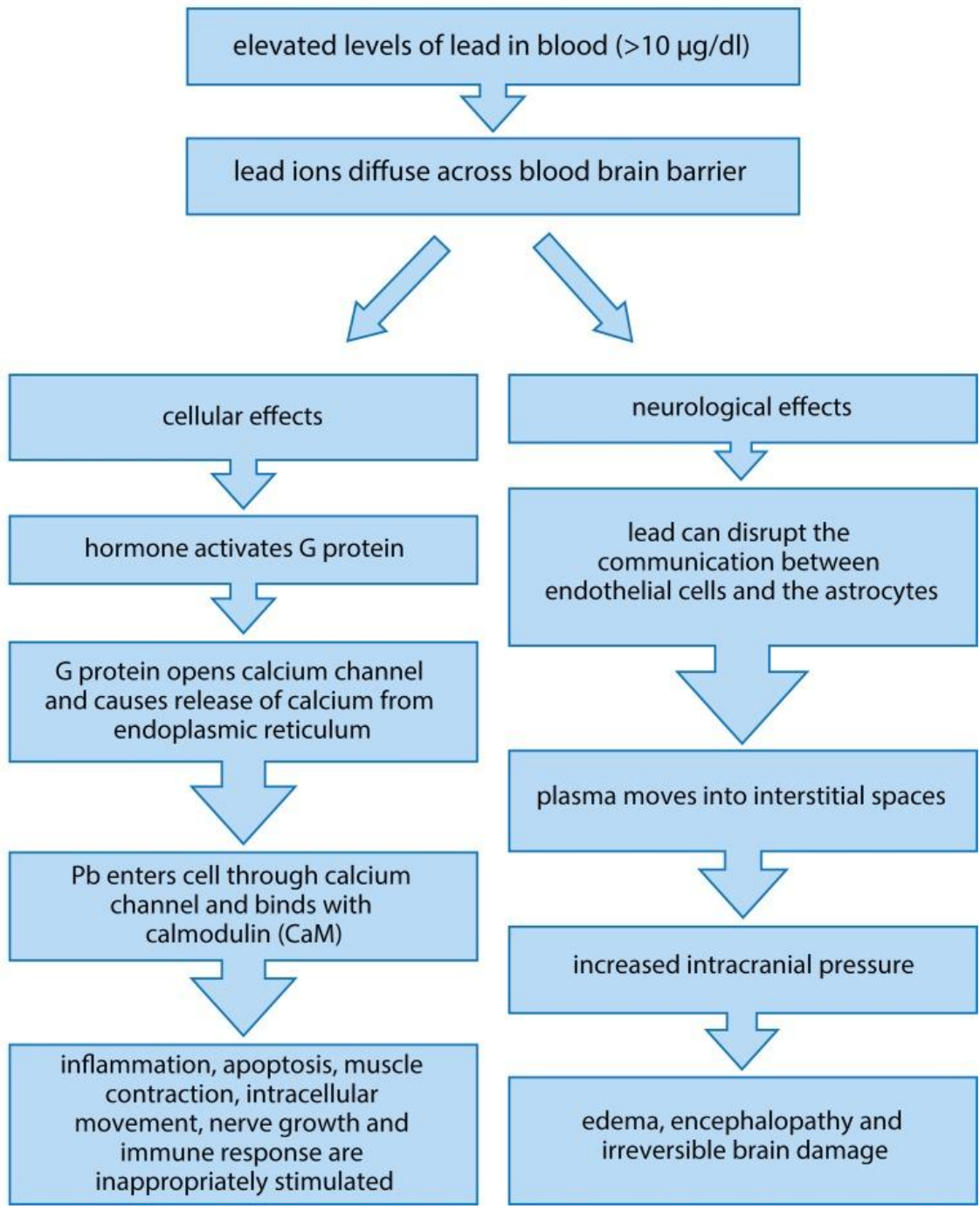


Fig 2.2 Effects of increased lead level in blood (Adapted from Brochin *et al.*, 2008).In: Jaishankar, *et al.*, 2014).

2.2.1.2 Cadmium

Cadmium is an element found in nature in mineral forms and is obtained for commercial uses mainly from cadmium ore, called greenockite, which is commonly found in association with zinc ore. The commercial production of cadmium ore is done by mining of zinc. It is commercially available as an oxide, chloride or sulfide. Cadmium metal is silver-white, blue-tinged lustrous metal. It is practically insoluble in water but some cadmium salts are water soluble. Powdered cadmium can burn and release corrosive fumes (NTP, 2004).

Cadmium has a lot of applications such as, in producing pigments, NiCd batteries, as stabilizers in plastics, as a neutron absorbent in nuclear reactors, in metal plating and phosphate fertilizers production. It is released into the environment mainly through mining and smelting, and enters the food chain through uptake by plants from contaminated soil or water. Cadmium on the ground can move easily through soil layers and can be taken up into the food chain by certain plants (such as tobacco, potatoes, rice, other cereal grains and other vegetables) more avidly than they do with other heavy metals such as lead and mercury (NTP, 2004).

Humans are exposed to cadmium through eating of foods grown in cadmium contaminated soil and inhalation. Cigarette smokers are more exposed to cadmium than non-smokers, since tobacco plant takes up cadmium avidly from the environment (Mannino, Holguin and Greves, 2004). It is a heavy metal of great environmental and occupational concern.

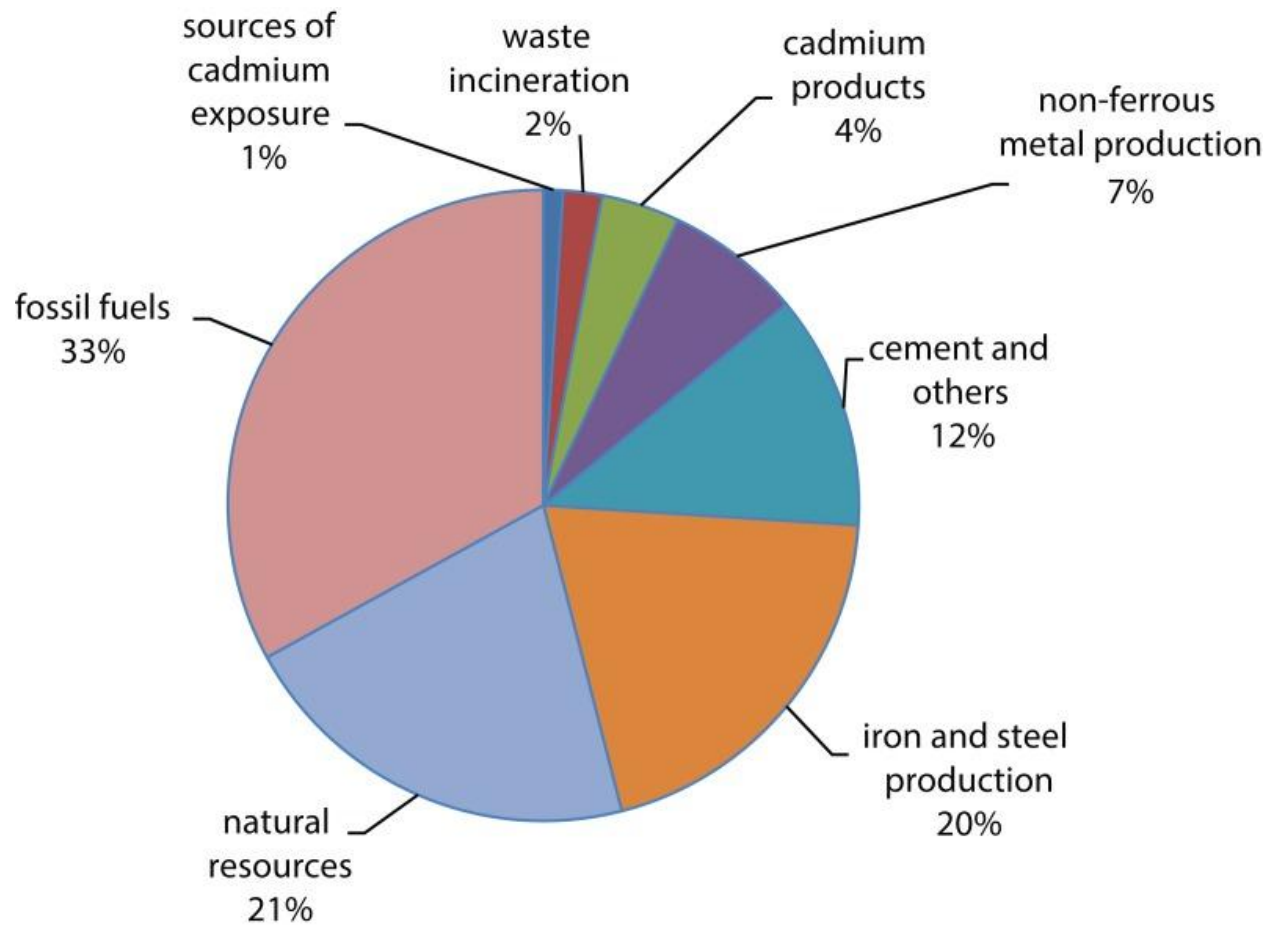


Fig 2.3. A relative contribution of different sources to human cadmium exposure (Adapted from Regoli, 2005). In: Jaishankar, *et al*, 2014).

2.2.1.2.1 Effects of Cadmium on Human Health

Cadmium has no known beneficial function in the human body. Therefore, any excessive accumulation in the body should be regarded as potentially toxic. The greatest cadmium accumulation is found in the kidney and liver. The biological half life of cadmium in the kidney is estimated to be between 6 to 38 years; and the half life of cadmium in the liver is between 4 and 19 years. These long half-lives show that humans do not have effective pathways for cadmium elimination. Therefore, the urinary cadmium excretion is slow; which constitute the major mechanism of excretion. Cadmium can interfere with copper and zinc metabolism Chronic cadmium inhalation may result in impairment of pulmonary function with obstructive changes; and bone changes can also result. Excessive acute cadmium exposure may lead to chemical pneumonitis, bronchitis, pulmonary edema and food poisoning (Flora, Mittal, Mehta, 2008).

Cadmium has been said to be carcinogenic. International Agency for Research on Cancer (IARC) and National Toxicology Program (NTP) have classified cadmium as a known human carcinogen (NTP, 2004); while American Conference of Industrial Hygienists (ACGIH) classifies cadmium as a suspected human carcinogen. However, the ability of an individual to sustain an unusual cadmium exposure depends on many factors such as the route of exposure, age, gender, smoking and other physiological factors (ATSDR, 2013).

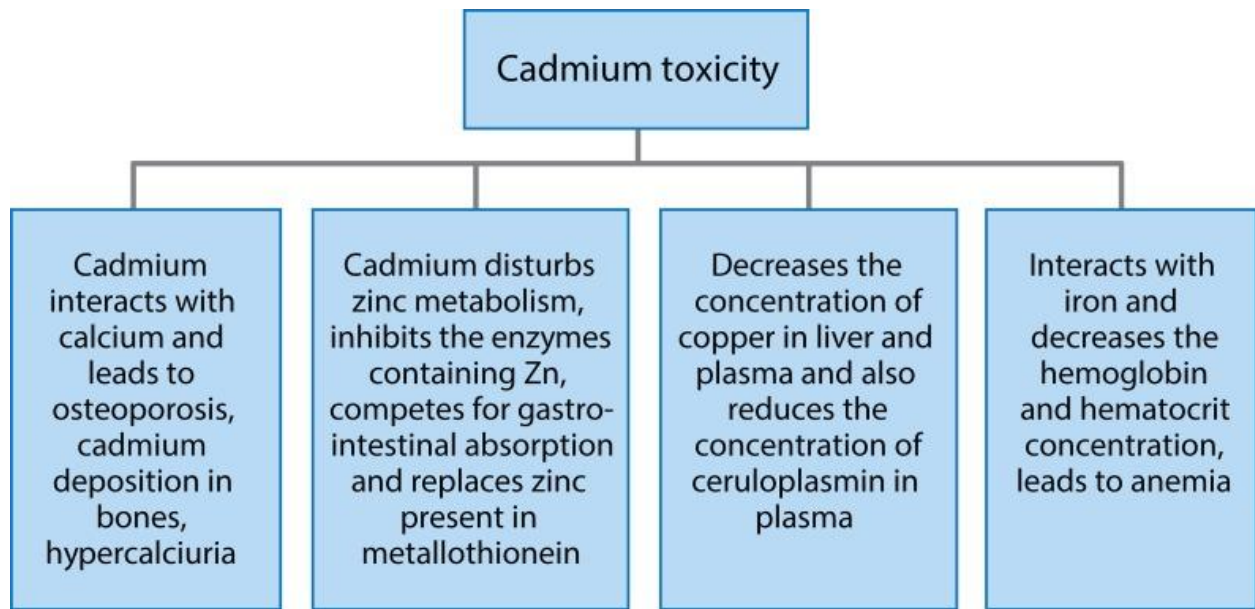


Fig 2.4 Values of cadmium toxicity (Adapted from Flora *et al.*, 2008).In: Jaishankar, *et al.*, (2014).

2.2.1.3 Chromium

Chromium is a naturally occurring shiny silvery-gray, brittle and hard metal found in the earth's crust. It is resistant to oxidation even at high temperature. It is found in various forms, from Cr (II) to Cr (IV) and is stable in the trivalent Cr (III). Chromium is mined as chromite (FeCr_2O_4) ore. Naturally chromium can be found in rocks, plants and soil (ATSDR, 2008; Tchounwou *et al*, 2012).

Chromium has a lot of applications such as in welding, chrome plating, metal ceramics and wood products. It is used in the production of synthetic rubies; as a catalyst in dyeing and in the tanning of leather. And chromium (IV) oxide (CrO_2) is used to manufacture magnetic tape (Lenntech, 2018; ATSDR, 2012).

Humans can be exposed to chromium through breathing, eating or drinking, and through skin contact with chromium or chromium compounds. Many people mainly obtain their chromium by eating food that contains chromium (III) because chromium (III) occurs naturally in many fruits, yeasts, vegetables and grains. Food stored in steel tanks and cans, may increase chromium concentration (Lenntech, 2018). Chromium enters the environmental matrices (air, water and soil) through various natural and anthropogenic sources especially from industries involve in; chromate production, stainless steel welding, metal processing and chrome pigment production. The main source of the increase in environmental concentration of chromium is said to be due to air and wastewater release of chromium, mainly from metallurgical and chemical industries. (Tchounwou *et al*, 2012).

2.2.1.3.1 Effects of Chromium on Human Health

Although Cr (III) is an essential nutrient for humans, its high intake can cause skin irritation (Lenntech, 2018, Tavakkoli, Nasab, and Narges, 2017). Chromium (VI) is dangerous to human health. According to International Agency for Research on Cancer (IARC), Chromium (VI) is a human carcinogen and is listed in group 1 carcinogens (Tavakkoli *et al*, 2017). Other health complications associated with chromium includes; nasal problem, skin rash, stomach ulcer, lung problem, kidney and liver damage, alteration of genetic material, weakened immune system, digestive and reproductive complication and even death (ATSDR, 2008; Tavakkoli *et al*, 2017; Lenntech, 2018).

2.2.1.4 Iron

Iron is one of the most abundant elements on the earth's crust. It is a very important element for the survival of living things. There are two main types of dietary iron namely; heme and nonheme. Heme iron is found in the blood and meat of animal products while nonheme iron is found in plant sources, example, beans, molasses, spinach, pumpkin leaf, curry leaf, spinach and nuts (NIH, 2016; Edward, 2017). The body absorbs heme iron more easily but it contributes only about 10-15% of total iron intake for most people (NIH, 2016; Edward, 2017; Richard and Ines, 2010). Irrespective of the lower bioavailability of nonheme iron, plant-based foods seem to encourage more efficient processing of the iron in the body; this is likely due to the high vitamin C content of plant foods because vitamin C increases the bioavailability of iron (VRG, 2017; Edward,

2017). But as important as iron is to living things, larger amounts of this metal can be toxic and dangerous to health.

Iron has wide application in industries. It is one of the most widely refined metals in the world. It is used in building materials, machinery, cookware tools, motor vehicles, and steel (RSC, 2017; AMA, 2017).

2.2.1.4.1 Effects of Iron on Human Health

As important as iron is to the body only trace amounts is required. Too much iron can be dangerous to the body. This is because there is no physiologic mechanism that can excrete iron from the body (Edward, 2017; Richard and Ines, 2010). So it is important to find the right balance for the body need. The risk of excess iron exposure is greater in anthropogenic activity such as mining from the earth (Edward, 2017). Occupational workers who are highly exposed to asbestos (contains almost 30% of iron) are at high risk of asbestosis, which is said to be the second most important cause of cancer. Asbestos associated cancer is linked to free radicals (Jaishankar, *et al*, 2014). Excess iron uptake poses a serious health challenge especially in meat eating countries because it increases the risk of cancer (Beguin, Aapro, Ludwig, Mizzen and Osterborg 2014; Jaishankar, *et al*, 2014). Also, children are highly susceptible to iron toxicity since they are exposed to a lot of iron-containing products (Jaishankar, *et al*, 2014). Other health complications associated with iron toxicity includes; nausea, constipation and reduced zinc absorption (Edward, 2017).

2.2.1.5 Zinc

Zinc is a metal with great importance. Industrially, zinc has a lot of applications; it is commonly used as an anti-corrosion agent. Zinc is also used in communication equipment, musical instruments and hardware. Zinc oxide is widely used as a pigment in paints and in rubber production. Zinc has semi conducting properties which makes it useful in varistors and photocopying products (Emsley, 2001).

Zinc is an “essential trace element” because very small amount of zinc is necessary for human health. Zinc plays vital physiologic roles in the growth and maintenance of plants and animals. But high concentrations of this metal can lead to negative health effects.

2.2.1.5.1 Effects of Zinc on Human Health

Although zinc is needed for proper growth and maintenance of the human body; excess zinc can cause adverse health effects. Excessive absorption of zinc suppresses copper and iron absorption. The U. S. Food and Drug Administration states that zinc damages nerve receptors in the nose, causing anosmia (inability to perceive odour or the loss of the sense of smell) (FDA, 2009).

Also, when the skin come in contact with skin powder, it can result in severe corrosive effects including ulceration, blistering and permanent scarring on the skin. If Zinc salt is ingested, it can react with water and stomach juice to release phosphine gas which can enter the blood stream and affect the lungs, liver, kidney, heart and central nervous system (Nriagu, 2007).

2.2.1.6 Copper

Copper is a reddish-brown, ductile, malleable metallic element. In its pure form, it can be shaped or molded without breaking. The most common alloys of copper are brass (copper and zinc) and bronze (copper and tin). Copper has a lot of applications in our daily lives such as; in electrical and electronics (example, power utilities, cell phones, lighting, and computers), construction and building (example, wiring, heating/refrigeration and plumbing), industrial machinery and equipment (example, on-site equipment, off-highway vehicles, transmission lines and manufacturing machinery), transport equipment (example, airplanes, cars, trucks and trains), as well as consumer and general products such as; household appliances, coins, cookware and currency (Harmon, Oso and Webb, 2013; USGS, 2014; CDAI, 2014; Stanley, Wilkinson, Moreno, Maier & Chief, 2015). It is an excellent conductor of heat and electricity; hence, it is widely used in electrical wiring (MEC, 2018; Stanley, *et al*, 2015). Also, copper is an important trace element to living things since it plays active role in the health of plants and animals (MEC, 2018).

2.2.1.6.1 Effects of Copper on Human Health

Although, the body homeostasis plays active role in the prevention of copper toxicity, but exposure of the body to excessive copper can result in a number of adverse health effects, which include: immunotoxicity, developmental problems, liver and kidney damage.

Critical targets of copper toxicity are the gastrointestinal tract and liver (ATSDR, 2014). Human's hepatic effects of copper are dependent on several factors including genetics, age and copper intake. Symptoms of hepatic effects may include centrilobular necroses and jaundice. In infants and children, liver effects may include Wilson's disease, Indian cirrhosis and idiopathic copper toxicosis. Also, copper is irritating to the respiratory tract especially when exposed to copper dust. (ATSDR, 2014).

2.3 Mechanism of heavy metal uptake by plants

Reports have shown that increase in anthropogenic activities have led to increase in the release of heavy metals into the environment (Fosu-Mensah , Addae, Yirenya-Tawiah and Nyame , 2017). Plants absorb these heavy metals basically through their roots (root uptake), leaves (foliar uptake) and shoots. The root uptake is through xylem and phloem, while the foliar uptake is basically through the stomata. For example, particulate matter (PM) containing heavy metal can be absorbed through foliar organs of plants after wet or dry deposition of atmospheric fallouts on plant canopy. Foliar uptake of heavy metal depends basically on factors such as the morphology and surface area of the plant leaves, the physico-chemical characteristics of the cuticle and metals, the chemical and physical form of the adsorbed metal, the surface texture of the leaves, exposure duration, environmental condition and plant species (Shahid, Dumat, Khalid, Schreck and Xiong *et al.*, 2016). Sources of heavy metals uptake in vegetables reported in literature are due to high traffic density, pesticides, insecticides (Echem and Kabari, 2012), use of fossil

fuels, dust, metals from industries (Kalagbor, Barisere, Barivule, Barile and Bassey, 2014), planting vegetables on waste water drain or irrigating with waste water (Onekutu, Oluma and Dajoh, 2018; Sharma, Katnoria and Nagpal, 2016); fertilizers and rainfall in highly atmospheric polluted areas (Sobukola, Adeniran, Odedairo and Kajihansa, 2010; Otitoju, Akpanabiatu, Otitoju, Ndem, Uwah, *et al*, 2012), as well as contaminated soil from other sources such as waste disposal, sewage sludge, smelting, mining as well as other industrial activities (Orubite, Ogunka-Nnoka and Okpokwu, 2015; Nwoko *et al.*, 2014; Osabolien, Otutu and Oluya, 2013; Ipeaiyeda and Dawodu, 2008).

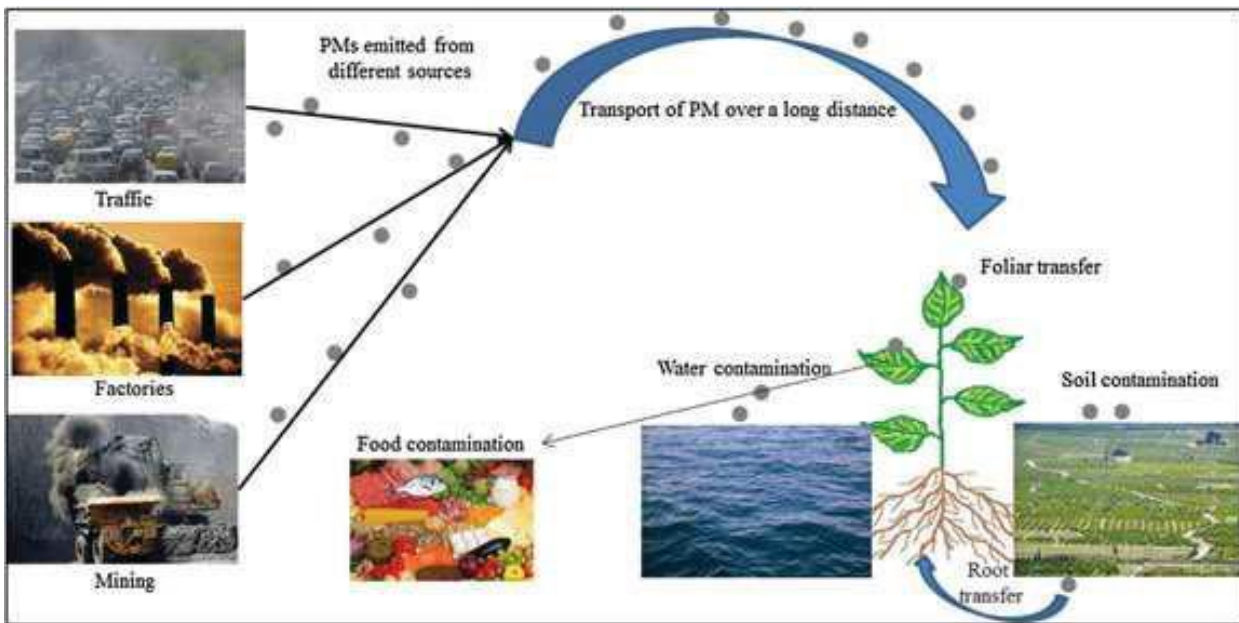


Fig 2.5. Heavy metal emission into atmosphere from different industrial activities, transfer over long distances in air, deposition and absorption by plant foliage, and possible risks of food chain contamination (Shahid, *et al*, 2016).

2.4 Workdone on heavy metal concentration in vegetables around urban areas

The heavy metal concentration of six heavy metals (Cu, Zn, Fe, Cr, Cd, and Pb) were determined in garden lettuce (*Lactuca sativa* L.) from a roadside farm, Badagry expressway, Lagos, Nigeria, using atomic absorption spectrophotometer after pressurized digestion with hydrochloric acid (HCl), sulphuric acid (H₂SO₄) and nitric acid (HNO₃). The plant was divided into roots, leaves and stems. The results obtained showed that Fe had the highest concentrations in the stem (14.681±11.621mg/kg), second to Zn in the leaf (0.062±0.047mg/kg) while Cr shows the lowest levels (0.001±0.000mg/kg) in the whole plant organ studied. When the results were compared with the permissible levels set by the FAO and WHO, heavy metals levels were found to be within safe limit. The metal uptake differences by parts of the plant were attributed to plant differences in the tolerance to heavy metals. However, the researchers advised that with the increase in vegetable consumption by man, the situation could worsen in future (Adu *et al*, 2012).

Okon, *et al.*, (2015) assessed the heavy metal concentration of seventeen heavy metals in the leaves of fluted pumpkin (*Telfairia occidentalis*) planted along road side in Calabar, Cross River State, Nigeria, using Particle Induced X-ray Emission (PIXE) spectrometry. The heavy metals considered were Magnesium (Mg), Aluminium (Al), Silicon (Si), P(Phosphorus), Sulphur (S), Chlorine (Cl), Potassium (K), Calcium (Ca), Titanium (Ti), Chromium (Cr), Manganese (Mn), Iron (Fe), Nickel (Ni), Copper (Cu), Zinc (Zn), Rubidium (Rb) and Strontium (Sr). 10 stands of fluted pumpkin were planted 1.5m away from the end of the road at 10 different locations within Calabar metropolis. Out of these,

5 were planted in a high traffic density location, while the other 5 were planted in a low traffic density location and 1 stand was planted in a farm 3Km away from the road to act as control experiment. The plants were well monitored and left to grow for three months until the leaves were matured enough for collection. The results obtained showed that K with the range of 20066.4 ± 78.3 to 56562.8 ± 118.8 ppm had the highest concentrations, while Zn with the range of 1.2 ± 3.3 to 41.5 ± 4.5 had the least concentrations. The samples were rich in mineral elements and were detected in the 10 sample locations. It was also observed that areas with the highest number of vehicles plying sample locations recorded the highest levels of heavy metals compared to areas with low traffic density.

The trace metals (Pb, Cd, Cr and Cu) contamination of three vegetables (Fluted pumpkin – *Telfairia occidentalis*, Waterleaf – *Talinum triangulare*, and Green – *Amaranthus hybridus*) were assessed around the urban area of Owerri, Imo State, Nigeria, using atomic absorption spectrophotometer after digestion with HNO_3 and HCl. The sampling locations were divided into 4 groups based on the level of urban activities, namely: very high urban activity, high urban activity, low urban activity and suburban activity. The soil sample of the different locations was also collected and assessed. The shoots of washed and unwashed samples were sub sampled and analysed for heavy metal contamination. The results showed the presence of the heavy metals in almost all the sample locations. The Trace Metal Pollution Index (TPI) ranged from 0.57 to 1.72. Also, the results showed that washing significantly reduced trace metal contamination of vegetables. When the results were compared with WHO/ FAO standards, it was shown that the results did not

exceed the safe limits. However, Cd exceeded the safe limit in washed vegetable tissue in some locations (Nwoko, *et al.*, 2014).

Echem and Kabari, (2013) determined the heavy metals ((Fe, Zn, Cr, Pb and Cd) content of bitter leaf (*Vernonia amygdalina*) grown along heavy traffic routes in Port Harcourt, using atomic absorption spectrophotometer after digestion with hydrochloric acid. The control location was Bori, Khana local government Area in Rivers State. The samples were collected in three different locations. The mean concentration of heavy metals were 3.22, 0.325, 0.042, ND and 1.03(mg/kg) for Fe, Pb, Cr, Cd and Zn respectively while that of the control was 2.21, 0.156, 0.024, ND and 0.84 (mg/kg) for Fe, Pb, Cr, Cd and Zn respectively. Therefore, the heavy metal concentrations of vegetables were higher in areas with high traffic routes than the control.

In Port Harcourt, Rivers State, Nigeria, four vegetables namely: bitter leaf(BL), fluted pumpkin(FP), saint leaf (SL)and water leaf(WL); also a crop - plantain flour (PF) were analyzed for the presence of nine heavy metals (Mn, Fe, Cu, Zn, Ni, Cd, Co, Zn and Cr) using AAS and further comparison with Energy Disperse x-ray Spectroscopy (EDS) after acid digestion of the samples with trioxonitrate (V) acid, HNO₃ and tetraoxchlorate (VII) acid, HClO₄ in the ratio (4:1). The samples were collected during the dry spell period (February), less frequent rainfall (September) and heavy rainfall (June). Soil samples were also collected alongside the plants and analyzed. The results showed the presence of the heavy metals with some having concentrations above the WHO/FAO acceptable limits. The AAS results showed that Co had the highest concentration and is consistently

high for all four vegetables followed by Fe while Pb has the least concentrations. The order of concentration is as follows: Co > Fe > Ni > Mn > Zn > Cd > Cu > Cr > Pb, while the trend for most metal concentrations in the samples studied is WL > SL > BL = FP > PF. All the above heavy metals were also detected in the soil samples. The heavy metal concentration for Fluted pumpkin during the period of peak rainfall for Mn, Fe, Cu, Zn, Pb, Cr, Ni, Cd and Co was 49.25, 217.50, 10.75, 38.25, 1.50, 5.00, 112.75, 8.25 and 752.50 (mg/Kg) respectively. The concentrations of most of the metals under study were highest when the rains were less frequent or gone - as in the dry spell period (Kalagbor, Emmanuel, Oyewole, 2015).

2.5 Health risk parameters

There are parameters used to assess the health risk associated with the ingestion of heavy metals from vegetables. These parameters include; Target Hazard Quotient (THQ), Daily Intake of Metals (DIM), Health Risk Index, Hazard Index (HI), etc.

2.5.1 Target Hazard Quotient (THQ)

THQ is a non-carcinogenic risk estimation of heavy metals consumption. It is a ratio of the determined dose of a pollutant to a reference level considered harmful. If the ratio is equal to or greater than 1, an exposed population is at risk. (Kingsley & Uchenna, 2018; Adedokun, Njoku, Akinola, Adesuyi and Jolaoso, 2016).

2.5.2 Daily Intake of Metals (DIM)

DIM is the average estimation of the daily metal loading into the body system for a specified body weight of a consumer. It is used to assess the health risks associated with the consumption of heavy metal via oral exposure (Kingsley & Uchenna, 2018). This does not consider the possible metabolic ejection of the metals but can easily tell the possible ingestion rate of a particular metal (Adedokun, *et al* , 2016).

2.5.3 Health Risk Index (HRI)

HRI is the ratio of the daily intake of metals to the oral reference dose of metals.

Generally, $HRI < 1$ means that the exposed population is safe of metals health risk while $HRI > 1$ means the exposed population is at risk (Adedokun, *et al*, 2016; Khan, Lin, Zhang, Huc, Zhu, 2008),

2.5.4 Hazard Index (HI)

HI is used to evaluate the potential risk to human health when more than one heavy metal is involved. Since different pollutants can cause similar adverse health effects, it is often appropriate to combine Hazard Quotients (HQs) associated with different substances. HI is the summation of the THQ of different metals (Kingsley & Uchenna, 2018).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

Obio/Akpor is one of the 23 local governments of Rivers state, found in the south southern part of Nigeria, otherwise called the Niger Delta Region of Nigeria. There are many industries in the study area, and the activities of this area results in the release of different gases and particles into the atmosphere and soil. These activities over time compromise the standard of air, soil and water (Egwuogu, Okeke, Emenike and Abayomi,2016).

Obio/Akpor LGA of Rivers State, Nigeria covers about 260 km². It is generally a lowland area with average elevation below 30m above sea level. Its geology comprises basically of alluvia sedimentary basin and basement complex (Alaminiokuma&Ofuyah, 2017; Eludoyin, Wokocha and Ayolagha, 2011). It is bounded by Ikwerre LGA to the north, Port Harcourt LGA to the south, Oyigbo LGA to the east and Emohua LGA to the west(Arokoyu, Ogoro and Amanoritsewo, 2015). It is located between latitudes 4° 45'N and 4° 60'N and longitudes 6° 50'E and 8° 00'E. According to population census in 2006 (National Bureau of Statistics, 2006) the total population size of Obio/Akpor LGA was 464,789 (Egwuogu, *et al*, 2016).

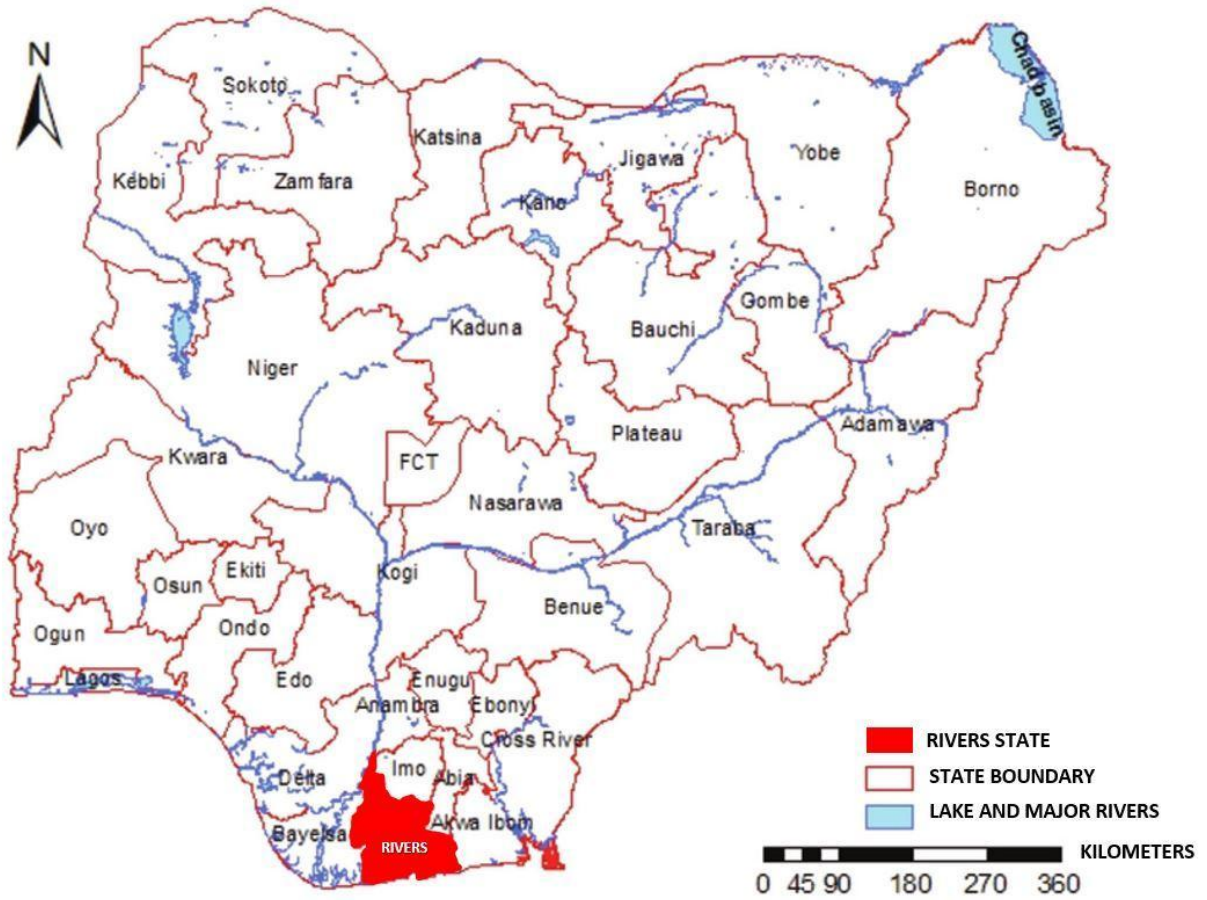


Fig 3.1. Map of Nigeria showing Rivers State

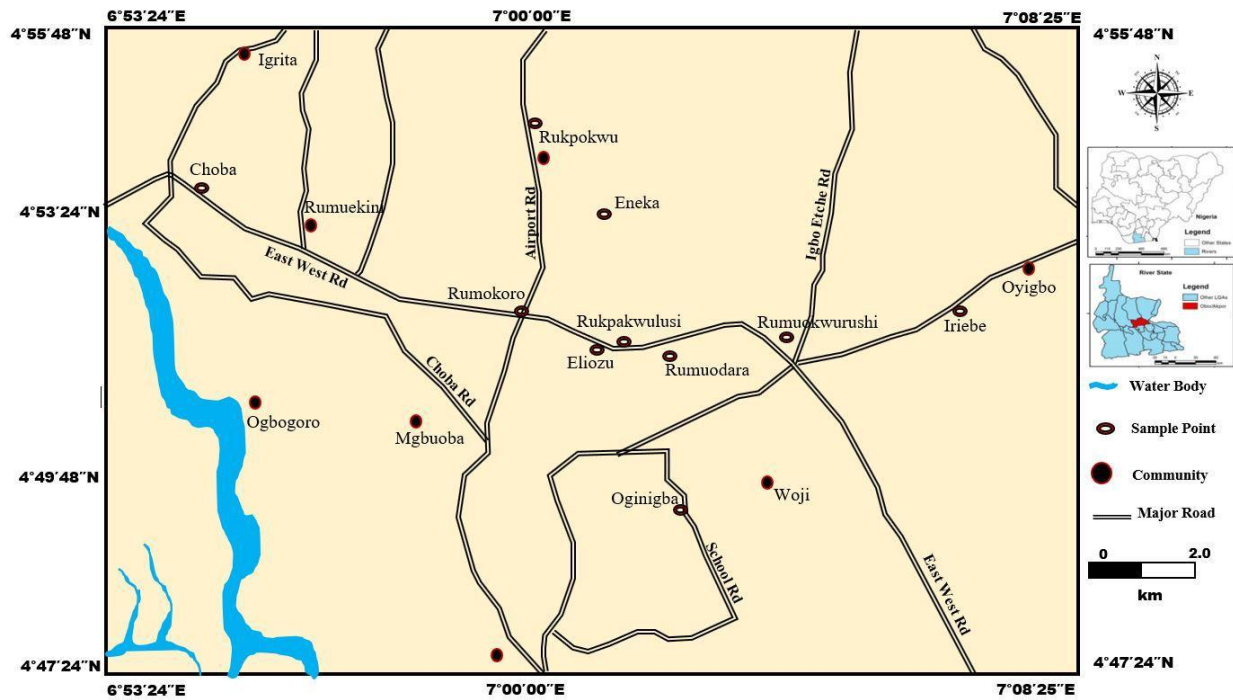


Fig 3.3. Map of Obio/Akpor and Environs showing sample locations

CORDINATES:

Longitudes: 6⁰53'24''E - 7⁰08'25''E

Latitude: 4⁰47'24''N-4⁰55'48''N

Elevation above sea level: 24.8m

3.2 Climate

Obio/Akpor lies in the tropical wet climate zone, characterized by abundant rainfall with little dry season. Rainfall is significant most months of the year, ranging from 2000 and 2500mm with temperature up to 25⁰C and a relatively constant humidity (Alaminiokuma&Ofuyah, 2017; Eludoyin, *et al*, 2011). The relief is generally lowland which has an average of elevation between 20 and 30m above sea level. The soil is usually sandy or sandy loam and is always leached due to the heavy rainfall experienced in this area (Egwuogu, *et al*, 2016; Eludoyin, *et al*, 2011).

3.3 Vegetation

The vegetation found in this area includes raffia palms, thick mangrove forest and light rain forest (Alaminiokuma&Ofuyah, 2017; Egwuogu, *et al*, 2016; Eludoyin, *et al*, 2011).

3.4 Hydrology

The study area is well drained with both fresh and salt water. The salt water is caused by the intrusion of seawater inland, thereby making the water slightly salty (Egwuogu, *et al*, 2016).

3.5 Economic Activities

Obio/akpor, located in Port Harcourt metropolis is one of the major centres of economic activities in Nigeria. Since the area is rich in crude oil, it is a home of many industries, filling stations, etc. The popularly known T/Amadi industrial area is located in this area. The inhabitants of the area are the Ikwerre nativity of Rivers State. The major occupation

of the inhabitants is farming and trading. The acquisition of crop farms from peasant farmers for crude oil exploration, exploitation and production as well as other economic activities has deprived the farmers of tangible areas of farmland which has caused loss of farm income and output. Therefore, the inhabitants of the area have ventured into other white collar jobs for survival (Ojimba, 2011).

3.6 Sampling stations

The sample population is ten (10) communities/villages within Obio/Akpor. These communities/villages were selected based on the serious industrial and construction activities going on in these area and major roads located within these communities. They are: Choba, Rumuokoro, Rumuodara, Iriebe, Oginigba, Rumuokwurushi, Rukpakwulusi, Eliozi, Eneka and Rukpokwu.

3.7 Sources of data

The data used for this research was sourced from primary data. The data was collected from the study area and then analyzed in the laboratory. The results obtained were compared with secondary data like WHO/FAO standard and previous works done by other researchers in this area, from which the conclusion and recommendation on this work were drawn.

3.8 Reliability of instrument

All the instruments used in the analysis were all reliable. The instruments used included; pH meter, model Janway 3510 used to determine soil pH. Electronic balance

(Model:WT5002) used to weigh samples. Atomic Adsorption Spectrometer (Model: Agilent 55B) used to determine the concentrations of Cu, Cr, Cd, Zn, Pb and Fe in both vegetable and soil samples.

3.9 Sample Collection

With the aid of a sharp knife, fluted pumpkin (*Telfairia occidentalis*) was collected from ten locations within Obio/Akpor LGA for investigation. Vegetables were collected in areas with high traffic or serious industrial and construction activities. Then one of the samples was collected from a garden in a residential area (Rumuodara) to act as control. Similarly, the study area was divided into three major grids Grid 1(Choba), Grid2 (Rumuokwurushi) and Grid 3(Oginigba). With the aid of a soil auger, soil sample (0-15cm) was collected from each sample grid and tied in an airtight polythene bag. Each of the plant and soil samples in an airtight polythene bag was labeled according to the location to avoid mix up of samples. The samples were collected in the month of June during the raining season.

3.10 Sample preparation

Fluted Pumpkin (*Telfairia occidentalis*) collected from the sampling locations were air-dried and blended to pass through 2mm sieve. Then, they were taken to the laboratory for analysis. Also, Soil sample (0-15cm) was collected in each sample grid using an airtight polythene bag. Part of the soil sample in an airtight polythene bag was immediately taken to the laboratory for analysis. The remaining part of the soil sample was air-dried to pass through a 2mm sieve and was also taken to the laboratory for analysis.

3.11 Laboratory analysis

Analytical Procedure for Trace Metal Determination

The air-dried vegetable samples were sieved using Whatman Filter Paper (2mm). One gram of each of the vegetable sample was weighed using Electronic balance (Model:WT5002) into a 50ml beaker, followed by the addition of 5ml of analytical grade acid HNO_3 and 5ml analytical grade acid HCl . The mixture was allowed to stand for some time. Then the mixture was heated at a temperature of about $80\text{-}90^\circ\text{C}$ for one hour thirty minutes with electric hot plate (HP 220, UTEC products Inc., Albany N. Y., USA) until a clear solution was obtained. After cooling, the solution was made up to a final volume (50ml) with distilled water in a volumetric flask. Similar procedure was carried on 1g air-dried soil samples. The metals (Cu, Cr, Cd, Zn, Pb and Fe) were determined on both vegetable and soil samples using Atomic Absorption Spectrophotometer (AAS) (model: Agilent Technology (Spectra 55B), Australia). Analysis of each sample was carried out three times to obtain representative results and the data reported in mg/kg.

Analytical Procedure for Physicochemical Characteristics in soil

(a) Total Organic Carbon (TOC)

The total organic carbon (TOC) was determined using the non-refluxing method with slight adjustment (Figueiredo, Sato, Marchão, Madari, Benedito, *et al*, 2014).

(b) Cation Exchange Capacity

The Cation Exchange Capacity was determined using the method of Donald & Quirine, (2012).

(c) Total Nitrogen Cation Exchange Capacity

The Total nitrogen was determined by adopting the method of Xiuli & Xinghui, (2012) with slight adjustment.

(d) Electrical Conductivity

The method of Piper, (1942) was used to determine the electrical conductivity of soil samples (Rayment & Higginson, 1992).

(e) Soil pH Electrical Conductivity

The soil pH was determined using pH meter, model Janway 3510. A soil-liquid mixture was established in the ratio 1:25 for each of the soil samples, by dissolving 20g of the sieve samples in 50cm³ of water in a glass cylinder and the pH was determined by inserting the pH meter in each of the diluted samples. Before measurements, the pH meter was calibrated using standard buffer solutions.

(f) Bulk Density

The bulk density was determined by using the method of John, (1995). The moisture content and dry density of each of the soil samples was also determined.

(g) Soil textural class Bulk Density

The soil textural class was determined using the wet and dry sieve analysis method (Ruben & Susan, 2015; Curtis, 2005).

3.12 Statistical analysis

Collected data obtained from various parameters of vegetable samples were subjected to mean ± standard deviation (SD). Statistical differences were performed using one way analysis of variance (ANOVA) and significant means were grouped by Tukey’s multiple range tests at 5% significant level using Minitab statistical package version 16.

3.13 Method of calculating trace metal pollution index (TPI)

Trace Metal Pollution index was determined using the equation by Usero, Gonzalo-Regalado and Gracia (1997) (Nwoko *et al*, 2014).

$$TPI = (TC_1 \times TC_2 \times TC_3 \dots TC_n)^{1/n} \quad (1)$$

Where: TC is the concentration of n trace metals in vegetable samples.

3.14 Methods of calculating health risk parameters

To assess the health risks associated with the ingestion of heavy metals from vegetables, Target Hazard Quotient (THQ), Daily Intake of Metals (DIM), Health Risk Index (HRI) and Hazard Index (HI) were calculated.

Calculated Target Hazard Quotient (THQ) in Exposed Population

The THQ was calculated using the formula below: (Adedokun, *et al*, 2016)

$$\text{THQ} = \frac{\text{EF} \times \text{ED} \times \text{FIR} \times \text{C}}{\text{RFD} \times \text{WAB} \times \text{TA}} \times 10^{-3} \quad (2)$$

Where:

EF is the exposure frequency (350 days/year)

ED is the exposure duration (54 years, equivalent to the average lifetime of the Nigerian population)

FIR is the food ingestion rate (vegetable consumption values for South Western adult Nigerian is 65g/person/day) (Oguntona, 1998)

C is the metal concentration in the edible parts of vegetables (mg/kg)

RFD is the oral reference dose (Pb, Cd, Cu, Zn and Cr were 0.0035, 0.001, 0.040, 0.300 and 1.5 mg/kg/day, respectively) (Adedokun, 2016; USEPA IRIS, 2006) and the RFD of Fe was 0.65 (Kingsley & Uchenna, 2018; US EPA, 2013).

WAB is the average body weight (65kg for adult vegetable consumer in South Western Nigeria) (Oguntona, 1998)

TA is the average exposure time for non-carcinogens (ED x 365 days/year)

Calculated Daily Intake of Metal (DIM) in Exposed Population

The DIM was calculated using the equation below:

$$\text{DIM} = \frac{\text{C}_{\text{metal}} \times \text{C}_{\text{factor}} \times \text{C}_{\text{foodintake}}}{\text{Baverageweight}} \quad (3)$$

Where:

C_{metal} is the heavy metal concentration in vegetables (mg/kg)

C_{factor} is the conversion factor (0.085). The conversion factor of 0.085 is to convert fresh vegetable weight to dry weight (Adedokun, 2016)

C_{food intake} is the daily intake of vegetables which was 65g/day (Adedokun, 2016; Oguntona, 1998).

B_{average weight} is the average body weight, which was 65kg for this study (Adedokun *et al*, 2016; Oguntona, 1998).

Calculated Health Risk Index (HRI) in Exposed Population

The **HRI** was calculated using the formula below: (Adedokun, 2016)

$$\mathbf{HRI = \frac{DIM}{RFD}} \quad (4)$$

Calculated Health Index (HI) in Exposed Population

The **HI** was calculated using the formula below: (Kingsley & Uchenna, 2018).

$$\mathbf{HI = \sum THQ (THQ_1 + THQ_2 + THQ_3 + THQ_4 + \dots + THQ_n)} \quad (5)$$

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

This chapter deals with the presentation of data collected from the analysis in statistical form and calculations.

Table 4.1 Heavy metal concentration (mg/kg) of fluted pumpkin in the study area

S/No	Location	Cu(mg/kg)	Cr(mg/kg)	Cd(mg/kg)	Zn(mg/kg)	Pb(mg/kg)	Fe(mg/kg)
1.	Rumuokoro	ND	ND	0.35±0.00 ^c	36.77±0.02 ^a	1.51±0.01 ^b	298.01±0.01 ^e
2.	Rumuokwurushi	ND	1.49±0.01 ^a	ND	24.12±0.01 ^e	ND	382.51±0.01 ^c
3.	Iriebe	ND	ND	ND	22.59±0.01 ^f	1.51±0.01 ^b	416.06±0.01 ^a
4.	Oginigba	ND	ND	ND	30.64±0.01 ^b	2.01±0.01 ^a	384.72±0.01 ^b
5.	Eliozu	ND	ND	0.55±0.01 ^a	30.20±0.01 ^c	ND	275.61±0.01 ^g
6.	Choba	ND	ND	ND	10.13±0.06 ⁱ	ND	287.41±0.01 ^f
7.	Eneka	ND	ND	ND	20.43±0.01 ^h	1.00±0.00 ^c	357.71±0.01 ^d
8.	Rumuodara	ND	ND	ND	7.56±0.01 ^j	ND	261.42±0.01 ^h
9.	Rukpakwulusi	ND	ND	0.45±0.001 ^b	21.08±0.01 ^g	ND	296.86±2.32 ^e
10.	Rukpokwu	4.62±0.04 ^a	ND	ND	29.24±0.01 ^d	ND	273.62±0.01 ^g
	WHO/FAO*	73	1.3	0.2s	99.4	0.3	425

Columns bearing the same letters are not significantly different at 5% probability level

ND = Not Detected

WHO/FAO* = Joint FAO/WHO Food Standards, (2001) (Adu, *et al*, 2012)

Table 4.2 Heavy metal concentration (mg/kg) of soil in the study area

Location	Cu(mg/kg)	Cr(mg/kg)	Cd(mg/kg)	Zn(mg/kg)	Pb(mg/kg)	Fe(mg/kg)	TP1
Grid 1(Choba)	8.60±0.01 ^c	12.77±0.03 ^c	3.45±0.002 ^a	27.03±0.06 ^b	5.00±0.01 ^c	857.69±0.01 ^c	19.92
Grid 2 (Rumuokw-urushi)	9.81±0.01 ^b	19.95±0.01 ^a	0.35±0.001 ^c	15.82±0.01 ^c	6.50±0.01 ^b	875.47±0.03 ^a	14.27
Grid 3 (Oginigba)	17.51±0.01 ^a	17.93±0.06 ^b	0.50±0.006 ^b	51.50±0.01 ^a	8.50±0.00 ^a	873.37±0.06 ^b	21.00

Columns bearing the same letters are not significantly different at 5% probability level

4.1 Concentration of heavy metals in *Telfairia occidentalis*

Introducing heavy industries and vehicular traffic in Obio/Akpor is apt. there is a great risk of contamination of the vegetable due to uptake of heavy metals from polluted soils and exposure to contaminated air. Consumption of vegetables contaminated by trace metals may pose risk to human health. In this study, at least one of the studied heavy metals (Pb, Cu, Cr, Cd, Zn, and Fe) with varying concentrations was detected in *Telfairia occidentalis* in at least one of the ten different locations within Obio/Akpor (Table 4.1). Trace metal contamination of fluted pumpkin ranged from Cu:0.00±0.00-4.62±0.04mg/kg, Cr: Cr:0.00±0.00-1.49±0.0104mg/kg, Cd:0.00±0.00-0.55±0.0104mg/kg, Zn: 7.56±0.01-36.77±0.0204mg/kg, Pb:0.00±0.00-2.01±0.0104mg/kg and Fe: 261.42±0.01-416.06±0.0104mg/kg (Table 4.1). The order of heavy metal concentration was Fe>Zn>Pb>Cu>Cr>Cd.

Pb was found to be highest in Oginigba, followed by Iriebe, Rumuokoro and Eneka with mean values of 2.01mg/Kg, 1.51mg/Kg, 1.51mg/Kg and 1.00mg/Kg respectively. These values exceed the WHO/FAO (2001) safe limit of 0.3mg/Kg for edible plants (Adu *et al*, 2012). ANOVA shows that this result is statistically significant (P<0.05). Likewise, the soil Pb ranged from 5.00±0.01-8.50±0.0004mg/kg. The ANOVA shows that it is statistically significant at P<0.05. The soil Pb value of the study area is higher than the plant Pb. Therefore, the high plant lead value may be due to absorption of soil lead by plants (Echem, 2014). This study is in agreement with Nwoko, *et al*, 2014, who found out that *Telfairia occidentalis* has the ability to absorb lead. Soil lead in the study area may

be due to erosion of lead based paints, waste from battery and additives from gasoline. Plant lead may also be due to automobile emission (Sharma & Dubey, 2005). In:Jaishankar, *et al.*, 2014).

Zinc was found to be highest in Rumuokoro and lowest in Rumuodara with mean values of 36.77mg/Kg and 7.56 respectively. The plant zinc content did not exceed WHO/FAO (2001) safe limit of 99.40mg/Kg. However, ANOVA result shows that this value is statistically significant ($P < 0.05$). Similarly, the soil zinc ranged from 15.82 ± 0.01 - 51.50 ± 0.0104 mg/kg. ANOVA shows that it was significant at $P < 0.05$. In this study, the soil zinc is higher than the plant zinc. This result is in agreement with Kalagbor, *et al*, (2015) who opined that fluted pumpkin can absorb zinc. The source of zinc in the study area may be due to steel processing or burning of waste. Although, zinc is an essential trace element necessary for human health, but high concentrations of zinc can lead to adverse health effects such as anosmia (inability to perceive odour or the loss of the sense of smell) (FDA, 2009), damage to the lungs, liver, kidney, heart and central nervous system (Nriagu, 2007).

Cadmium was found in Elioju, Rukpakwulusi and Rumuokoro with mean values of 0.55mg/Kg, 0.45mg/Kg and 0.35mg/kg respectively. These values exceeded the WHO/FAO safe limit of 0.2mg/kg for Cd. The ANOVA shows that this result is significant at $P < 0.05$. This result is in line with the study of Echem, (2014), who did a similar study in Port Harcourt metropolis and found out that fluted pumpkin leaves bioaccumulate trace metals especially Cd. Similarly, the soil cadmium ranged from

0.35±0.001-3.45±0.00204mg/kg. The ANOVA showed that this result is significant at $P<0.05$. The soil cadmium is higher than the plant cadmium. This result is in line with Fosu-Mensah *,et al*, (2017) and Nwoko, *et al*, (2014) who found out that Cd exceeded the WHO/FAO safe limit in vegetables. Since the three locations with high Cd levels are areas with high traffic density, the result is also in agreement with Echem and Kabari, (2013) who found out that heavy metal concentrations of vegetable were higher in areas with high traffic routes within Port Harcourt metropolis.

Contrary, this result does not agree with Echem and Kabari (2012) who did a similar work within Port Harcourt metropolis and did not detect Cd in any of the locations. The disagreement between this work and that of Echem and Kabari (2012) may be because this work came later than theirs. Perhaps new anthropogenic activities must have been introduced in the area as at the time of this research which was not there as at the time they did theirs.

The high plant Cd may be due to atmospheric deposition on the plant by vehicular emissions and absorption by plant from soil Cd. The source of Cd in the study area may be due to fossil fuel and cement from construction sites. Cadmium is a metal of great environmental and occupational concern as it has been classified as a known human carcinogen (NTP, 2004). Also, excessive acute cadmium exposure may lead to pneumonitis, bronchitis, pulmonary edema and gastrointestinal problem. Cd is characterized by heavy traffic and burning of fossil fuel.

The plant chromium was detected in Rumuokwurushi only with mean value of 1.49mg/kg. The plant Cr mean value of 1.49mg/kg is above the WHO/FAO (2001) safe limit of 1.30. Also, ANOVA shows that this result is significant at $P < 0.05$. The soil chromium ranged from 12.77 ± 0.03 - 19.95 ± 0.0104 mg/kg. ANOVA shows that this result is significant ($P < 0.05$). The soil Cr was higher than the plant Cr. This result is in line with Adu, *et al*, (2012) who also detected chromium in vegetable sample. The high plant Cr may be due to absorption by plant. The source of Cr in the study area may be due to welding and other anthropogenic activities. Although, Cr (III) is an essential nutrient for humans, excessive intake can cause skin irritation (Tavakkoli, *et al*, 2017; Lenntech, 2015), stomach ulcer, lung problem, kidney and liver damage, reproductive complication and weakened immune system (Lenntech, 2018, ATSDR, 2008).

Plant copper was detected in Rukpokwu only with mean value of 4.62mg/kg. The mean Cu value of 4.62mg/kg is less than the WHO/FAO (2001) safe limit of 73.0mg/kg. However, statistically it is significant at $P < 0.05$. Also, the soil copper ranged from 8.60 ± 0.01 - 17.51 ± 0.0104 mg/kg. ANOVA result shows that it is significant ($P < 0.05$). The soil copper was more than the plant copper. This result is in line with Adu *et al*, (2012) who found out that copper level in vegetable were within safe limits. Okon, *et al*, (2015), also reported the presence of copper in *Telfairia occidentalis*. The source of copper in the study area may be due to waste from copper containing electrical gadgets. Although copper is an important trace element to living things, but exposure of the body

to excessive copper can lead to negative health impacts such as immunotoxicity, gastrointestinal disorder, liver and kidney damage (ATDSR, 2014).

Iron concentration was highest in Iriebe. This value was less than the WHO/FAO (2001) safe limit of 425.0mg/kg. However, statistically it was significant at $P < 0.05$. Likewise, the soil iron ranged from 857.69 ± 0.01 - 875.47 ± 0.0304 mg/kg. The ANOVA showed that this value was significant at $P < 0.05$. The plant iron is less than the soil iron. Iron is the most abundant metal in this study. Similarly, this is in line with Adu, *et al*, (2012), who also did a similar work in Lagos and found out that iron was the most abundant metal in the study. Also, Kalagbo, *et al* (2015) did a similar work in Port Harcourt and found out high iron accumulation in vegetables. The presence of iron in the study area could be due to iron base waste in the area. Iron is very important for the survival of living things but excessive iron in the body can result in nausea, constipation and reduced zinc absorption (Edward, 2017).

The trace metal pollution index (TPI) of the soil was in the order Oginigba (21.00) > Choba (19.92) > Rumuokwurushi (14.27). These values are relatively high and show serious soil heavy metal contamination in the study area (Table 2). Also, the TPI showed that Oginigba had the highest trace metal contamination. Similarly, soil Pb contamination was highest in this area. This may also be the cause of high Pb in fluted pumpkin leaf apart from atmospheric deposition and it may be due to high industrial activities in this location.

In terms of location, heavy metal contamination was in the order Iriebe (440.16mg/kg)>Oginigba(417.37mg/kg)>Rumuokwurushi(408.12mg/kg)>Eneka (379.14mg/kg)>Rumuokoro(336.64mg/kg)>Rukpakwulusi(318.39mg/kg)>Rukpokwu(307.48mg/kg)>Rukpakwulusi(306.36mg/kg)>Choba (297.54mg/kg)>Rumuodara (268.98). Iriebe had the highest heavy metal contamination followed by Oginigba. The two areas are areas of serious industrial activities in the study area.

The high concentration of plant heavy metal at Iriebe may be due to the steel village located in the area. Also, there was a serious construction work going on around the location as at the time the sample was collected. That was when the Port Harcourt-Aba express road was under construction by the Rivers State government and the vegetable farmland where the sample was collected was few steps away from the construction site. The farmland where the sample was collected was located along the Port Harcourt-Aba express way; therefore, atmospheric depositions due to vehicular emissions may have also contributed to the high heavy metal concentration at Iriebe.

In a similar vein, Oginigba is the area where the popular T/Amadi industrial area is located. The area is characterized by serious industrial and commercial activities. The farmland where the sample was collected was few steps away from a filling station and heavy diesel/petrol tanks park very close to the farmland. One could literally see diesel and gasoline droppings on the ground which drains directly into the farmland due to erosion. So, these may be some of the reasons Oginigba had a high level of heavy metal concentration.

However, Rumuodara recorded the least heavy metal concentration. Rumuodara is more of a residential area and the sample was collected from a garden inside a residential compound, this may be the reason it recorded the least value, however, all the trace metals detected at Rumuodara were statistically significant.

Also, the trace metals were not evenly distributed across the study area. Zn, Pb and Fe were found in the ten locations. However, Cu was found in Rukpokwu only, Cr was found in Rumuokwurushi only and Cd was found in Rumuokoro, Elioizu and Rukpakwulusi only. The variations in the presence of heavy metals in the different locations may be attributed to different activities going on in the different locations hence, introduce different heavy metals into the environment. It may also be due to variations in the absorption capacity of heavy metal by plants in the study area.

Furthermore, it has been established that washing of vegetables significantly reduce heavy metal concentration and thus suggest that atmospheric depositions on vegetables are a major source of trace metal contamination of vegetables in urban areas apart from adsorption of heavy metals by plants (Nwoko, *et al*, 2014).

Well, fluted pumpkin (*Telfairia occidentalis*) was chosen in this study against other vegetables because fluted pumpkin (*Telfairia occidentalis*) is one of the most consumed vegetables in the area because of its nutritional and medicinal values. Also, the vegetable can be planted and harvested within a short period since the soil of the area favors its cultivation. Likewise, the vegetable is one of the commercial plants of the indigenes of the area because of its “quick money” returns.

However, this work differs from other previous studies in the following ways. Firstly, before this research there was no research report on Iriebe recording the highest plant heavy metal concentration. Secondly, no known report on vegetable contamination within the popular T/Amadi industrial layout before this research has been reported. Thirdly, there was no known report where cadmium was detected in three different locations within the study area apart from this research work.

Table 4.3 Soil chemical characteristics of the study area

Location	Ph	EC ($\mu\text{S/cm}$)	CEC ($\text{Meq}/100\text{g}$)	Total N (%)	TOC (mg/g)	Bulk Density (g/cm^3)
Choba	8.963 \pm 0.006 _b	11140.3 \pm 0.6 _a	0.022 \pm 0.00017 _{3^b}	0.18 \pm 0.00058 _b	22.31 \pm 0.0115 _c	1.51 \pm 0.00577 ^a
Rumuok-wurushi	9.033 \pm 0.006 _a	8380.7 \pm 0.6 ^b	0.017 \pm 0.00011 _{5^c}	0.06 \pm 0.00115 _c	33.20 \pm 0.058 ^b	1.38 \pm 0.00115 ^b
Oginigba	8.943 \pm 0.006 _c	8020.3 \pm 0.6 ^c	0.024 \pm 0.00005 _{8^a}	0.22 \pm 0.00115 _a	37.93 \pm 0.0577 _a	1.51 \pm 0.00577 ^a

Columns bearing the same letters are not significantly different at 5% probability level

Table 4.4 Relationships between soil chemical properties and heavy metal uptake in plants

Soil Properties	Cu	Cr	Cd	Zn	Pb	Fe
Ph	-0.57	0.549	-0.344	-0.861	-0.289	0.404
	0.109 ^{ns}	0.126 ^{ns}	0.365 ^{ns}	0.003	0.451 ^{ns}	0.281 ^{ns}
EC	-0.685	-0.928	0.989	-0.312	-0.878	-0.977
	0.042	0.000	0.000	0.414 ^{ns}	0.002	0.000
CEC	0.621	-0.503	0.291	0.894	0.347	-0.352
	0.074 ^{ns}	0.167 ^{ns}	0.448 ^{ns}	0.001	0.360 ^{ns}	0.353 ^{ns}
Total Nitrogen	0.600	-0.527	0.317	0.882	0.321	-0.378
	0.088 ^{ns}	0.145 ^{ns}	0.406 ^{ns}	0.002	0.399 ^{ns}	0.317 ^{ns}
Total Organic Carbon	0.812	0.839	-0.942	0.489	0.953	0.918
	0.008	0.005	0.000	0.182 ^{ns}	0.000	0.000
Bulk Density	0.387	-0.715	0.536	0.740	0.082	-0.590
	0.303 ^{ns}	0.030	0.137 ^{ns}	0.023	0.834 ^{ns}	0.095 ^{ns}

ns = not significant

4.2 Soil chemical characteristics and heavy metal uptake in plants

The result of the soil chemical characteristics of the study area is as shown in table 4.3. pH varied from 8.943 ± 0.006 - 9.033 ± 0.006 , Electrical Conductivity (EC) varied from 8020.3 ± 0.6 - $11140.3 \pm 0.6 \mu\text{S}/\text{cm}$, Cation Exchange Capacity varied from 0.017 ± 0.000115 - $0.024 \pm 0.000058 \text{Meq}/100\text{g}$, Total Nitrogen varied from 0.06 ± 0.00115 - $0.22 \pm 0.00115\%$, Total Organic Carbon (TOC) varied from $22.31 \pm 0.0115 \text{mg}/\text{g}$ and Bulk Density varied from 1.38 ± 0.00115 - $1.51 \pm 0.00577 \text{g}/\text{cm}^3$ (Table 3).

Generally, the soil heavy metal contamination was more than that of the vegetable. The tendency of the vegetable to absorb heavy metals from the soil was found to be low. Mostly, soil physicochemical properties are responsible for metal plant uptake. Therefore, in the present study, soil factors such as pH, cation exchange capacity (CEC), total organic carbon (TOC), electrical conductivity (EC), total nitrogen, bulk density and type of soil were considered.

In table 4.4, pH was not significant in all the trace metals apart from zinc and ranged from 0.003-0.451, electrical conductivity was significant in all the trace metals apart from zinc and ranged from 0.000-0.414, cation exchange capacity was not significant in all the trace metals except in cadmium and ranged from 0.001-0.448, total nitrogen was not significant in all the trace metals except in zinc and ranged from 0.002-0.406 and total organic carbon was significant in all the trace metals except in zinc and ranged from 0.000-0.182. It has been established that heavy metal uptake by plants is pH dependent

(Adamczyk-Szabela, Markiewicz and Wolf, 2015). All these factors have interactive effect on plant uptake of heavy metals from soil.

Table 4.5 Target Hazard Quotient (THQ) and Hazard Index (HI) of *Telfairia occidentalis* in exposed population

Heavy Metal	THQ	HRI
Cu	0.111	9.825
Cr	0.001	0.085
Cd	0.432	38.000
Zn	0.074	6.593
Pb	0.413	36.57
Fe	0.477	42.289
HI = ΣTHQ	1.508	

Table 4.6 Daily intake rate (mg day⁻¹ person⁻¹) of heavy metal in vegetable

Heavy Metal	DIM (mg day⁻¹ person⁻¹)	* DI (mg day⁻¹ person⁻¹)	* UL (mg day⁻¹ person⁻¹)
Cu	0.393	0.9	10
Cr	0.127	-	-
Cd	0.038	0.000	0.064
Zn	1.978	8	40
Pb	0.128	0.000	0.240
Fe	27.488	8	45

*** Recommended daily intake (DI) and upper tolerable daily intake (UL) levels of**

heavy metals in foodstuffs (FDA, 2001; Garcia-Rico, 2007; Adedokun, 2016)

4.3 Health risk assessment

To ascertain the human health risk of consuming these heavy metals by the population, the Target Hazard Quotient (THQ), Daily Intake of Metal (DIM), Health Risk Index (HRI) and Hazard Index (HI) were calculated using equations 2, 3, 4 and 5 respectively and the results are presented in tables 4.5 and 4.6. The THQ ranged from 0.001-0.477, the HI value was 1.508 and the HRI ranged from 0.085-42.289 (Table 5) while the DIM ranged from 0.038-27.488 (Table 6).

The THQ is a ratio between the measured concentration and the oral reference dose, weighted by the length and frequency of exposure; amount ingested and body weight (Adedokun, 2016; Tsafe *et al.*, 2012). THQ value greater than 1 shows that a population is at risk of metal contamination. The THQ of Cu, Cr, Cd, Zn, Pb and Fe were 0.111, 0.001, 0.432, 0.074, 0.413 and 0.477 respectively (Table 5). From the result, the risk exposure of the target population to heavy metal was in the order Fe>Cd>Pb>Cu>Zn>Cr. The THQ of all heavy metals in this study was less than 1; therefore, it does not pose health risk concern. Adedokun, (2012) did a similar work at Lagos and found out that Cd, Pb, Cu, Zn and Cr did not pose health concern to the inhabitants of the study area.

DIM is use to calculate the amount of metal taken by an individual per day (Patrick-Iwuanyanwu & Chioma, 2017). The DIM results in table .6, were compared with the recommended daily intake of metals (DI) and the tolerable upper intake level (UL) established by the Institute of Medicine for people between the ages of 19 to 70 years (FDA, 2001; Garcia-Rico, 2007; Adedokun, 2016). It is obvious that the daily intake of

Cu (0.393) and Zn (1.978) are lower than the recommended daily intake level of metals and the tolerable upper intake level (UL). But the DIM of Pb (0.128), Cd (0.038) and Fe(27.488) exceeded the recommended daily intake level, however, fall within the tolerable upper intake level. Cr (0.127) is lower than the recommended oral reference dose (RfD) of 1.5mg/kg (USEPA, 2010). However, the tolerable upper intake level for Cr has not been established. Since, the DIM of Pb, Cd and Fe are above the recommended daily intake, the target population may be at risk of these metals exposure if the value increase above the UL. Similarly, Adedokun, *et al*, (2016) in his work at Lagos found out that the DIM of Pb and Cd in vegetable exceeded the recommended daily intake but falls within the UL.

The HRI of Cu, Cr, Cd, Zn, Pb and Fe were 9.825, 0.085, 38.000, 6.593, 36.570 and 42.289 respectively. Generally, $HRI < 1$ means that the exposed population is safe of metals health risk while $HRI > 1$ means the reverse (Adedokun, 2016; Khan *et al.*, 2008). In this study, the HRI of the metals considered are greater than 1 except Cr. Therefore, the population may be at risk of Cu, Cd, Zn, Pb and Fe exposure. Adedokun, *et al*, (2016) and Tsafe, *et al*, (2012) also gave similar reports on Cu, Cd, Zn, Pb and Cr.

Hazard index (HI) is used to evaluate the potential risk to human health when more than one heavy metal is involved. $HI > 1$ shows that a population is at risk. In this study, the HI was 1.508. This shows that the population may be at risk of consuming this vegetable.

Since heavy metals are non-biodegradable they can be harmful and cause serious health effects at certain level in the body. Also, vegetables are mostly consumed in the South-

south Nigeria because of its health benefits and they have been indiscriminate planting of these vegetables, therefore, the analysis of trace metals in leafy vegetables is very important because of its toxicity. These findings collaborate with the work of Adu, *et al*, 2016, who investigated heavy metals Fe, Cu, Zn, Cr, Cd and Pb content in vegetable and found out that all the trace metals were of varying concentrations in the vegetable, and were below the WHO/FAO safe limits. The findings also collaborate with the work of Adedokun *et al*, 2016, who did a similar work in Lagos, Nigeria and found out that vegetables including fluted pumpkin accumulate Cu, Zn, Cr, Cd and Pb at varying concentrations. He also found out that the THQ value of all the metals were below the permissible limits and therefore, did not pose risk, but with continuous consumption of vegetables the values may increase.

On the contrary, this work contradicts the work of Echem and kabari (2012) who did a similar work on cadmium in Port Harcourt metropolis but did not locate cadmium in any of the locations.

CHAPTER FIVE

5.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

This research work assessed the heavy metal concentration of Fluted pumpkin (*Telfairia occidentalis*) in Obio/Akpor LGA, of Rivers state. The fluted pumpkin was obtained in ten different locations within the study area, including one location as control and analyzed for heavy metals. The heavy metals studied were lead, copper, iron, chromium, cadmium and iron. The results of analysis were compared to WHO/FAO standard. The human health risk of the inhabitants of the study area consuming contaminated vegetable was also assessed.

Heavy metal concentration of the vegetable varied across the local government. Heavy metal contamination in the locations was in the order Iriebe>Oginigba>Rumuokwurushi>Eneka>Rumuokoro>Rukpakwulusi>Rukpokwu>Rukpakwulusi>Choba>Rumuodara. The least concentration was recorded in Rumuodara which was the control. All the heavy metals were below the WHO/FAO permissible limits but were significant at 5% probability level. The order of heavy metal concentration was Fe>Zn>Pb>Cu>Cr>Cd.

The target hazard quotient (THQ) showed that the population was not at risk of heavy metal contamination. The daily intake of metal (DIM) when compared to the recommended daily intake of metals and the tolerable upper intake level showed that the

population may be at risk of heavy metal contamination when this vegetable is consumed except in chromium. The hazard index (HI) was greater than one and showed the population may be at risk of heavy metal concentration. Also, the health risk index (HRI) showed that the population may be at risk of heavy metal contamination of vegetable except in chromium.

5.2 Conclusion

All the trace metals studied were found in fluted pumpkin in varying concentrations. Although, the trace metals were below the WHO/FAO acceptable limits but there were all statistically significant. The result also shows that areas with high industrial and traffic activities recorded higher values of heavy metal contamination while the residential area recorded the least. The HRI and HI values show that the population may be at risk of heavy metal contamination. The DIM value shows that Pb and Cd were below the UL but exceeded the recommended daily intake. This is worthy of concern because Pb and Cd are heavy metals of serious environmental concern. However, this result is only one route of heavy metal exposure, if other routes of exposure are considered the population may be at a higher risk of heavy metal contamination. Therefore, there is need for continuous monitoring of trace metal contamination of vegetables grown in urban areas to reduce the risk associated with trace metal contamination.

5.3 Recommendation

After reviewing the above study it may be recommended that:

1. Since the soil heavy metals were generally higher than the plant heavy metal concentrations, more research should be done on the heavy metal concentration of the soil of this area
2. There should be more research on the health risk of consuming heavy metals of the neighboring towns, villages or cities close to this area.
3. Awareness should be raised about the dangers of indiscriminate planting of vegetables.
4. Planting of vegetables on areas with serious industrial and commercial activities such as; construction sites, around filling stations, markets, areas with serious traffic, etc. should be discouraged.
5. Farmers should be sensitized on the advantages of adopting best practices for cultivation of vegetables.

5.4 Contribution to Knowledge

Findings from the above study showed that the heavy metals did not occur naturally but may have been introduced into the environment by anthropogenic activities. This is because areas with serious industrial, commercial and traffic activities within the area of

study recorded higher values of heavy metal concentrations than the residential area. Likewise, there was no location in the study area where all the six heavy metals were detected at the same time but at least one heavy metal was found in each of the locations; meaning the heavy metals were not evenly distributed in the study area.

Iron had the highest concentration of heavy metal in all the locations within the study area with Iriebe recording the highest. The high level of Fe recorded in Iriebe may be due to the popular steel village located in this area.

Cadmium was detected in Rumuokoro, Elioazu and Rukpakwulusi. These are areas with serious traffic routes; they cut across the popular East/West road in Nigeria. This result does not agree with Echem and Kabari (2012) who did a similar work within Port Harcourt metropolis and did not detect Cadmium in any of the locations. The disparity could be because this work came later than theirs; hence, there is need for continuous monitoring of heavy metal concentration in this area.

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APPENDICES

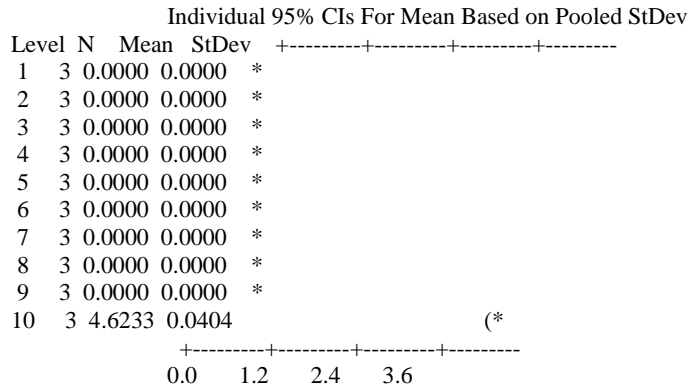
Appendix 1

Statistical Analysis (Minitab statistical package version 16)

One-way ANOVA: Cu versus Location L

Source	DF	SS	MS	F	P
Location L	9	57.71307	6.41256	39260.59	0.000
Error	20	0.00327	0.00016		
Total	29	57.71634			

S = 0.01278 R-Sq = 99.99% R-Sq(adj) = 99.99%



Pooled StDev = 0.0128

Grouping Information Using Tukey Method

Location L	N	Mean	Grouping
10	3	4.6233	A
9	3	0.0000	B
8	3	0.0000	B
7	3	0.0000	B
6	3	0.0000	B
5	3	0.0000	B
4	3	0.0000	B
3	3	0.0000	B
2	3	0.0000	B
1	3	0.0000	B

Means that do not share a letter are significantly different.

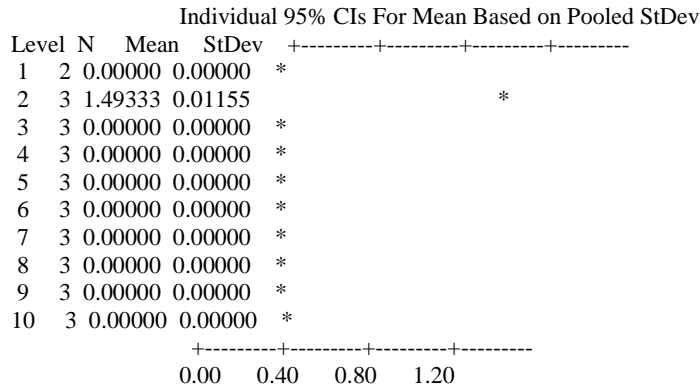
Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Location L

Individual confidence level = 99.80%

One-way ANOVA: Cr versus Location L

Source	DF	SS	MS	F	P
Location L	9	5.998051	0.666450	47484.57	0.000
Error	19	0.000267	0.000014		
Total	28	5.998317			

S = 0.003746 R-Sq = 100.00% R-Sq(adj) = 99.99%



Pooled StDev = 0.00375

Grouping Information Using Tukey Method

Location L	N	Mean	Grouping
2	3	1.49333	A
10	3	0.00000	B
9	3	0.00000	B
8	3	0.00000	B
7	3	0.00000	B
6	3	0.00000	B
5	3	0.00000	B
4	3	0.00000	B
3	3	0.00000	B
1	2	0.00000	B

Means that do not share a letter are significantly different.

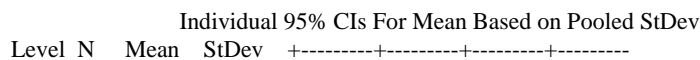
Tukey 95% Simultaneous Confidence Intervals All Pairwise Comparisons among Levels of Location L

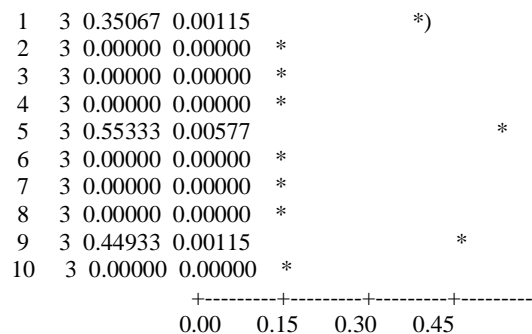
Individual confidence level = 99.79%

One-way ANOVA: Cd versus Location L

Source	DF	SS	MS	F	P
Location L	9	1.343683	0.149298	41471.69	0.000
Error	20	0.000072	0.000004		
Total	29	1.343755			

S = 0.001897 R-Sq = 99.99% R-Sq(adj) = 99.99%





Pooled StDev = 0.00190

Grouping Information Using Tukey Method

Location L	N	Mean	Grouping
5	3	0.55333	A
9	3	0.44933	B
1	3	0.35067	C
10	3	0.00000	D
8	3	0.00000	D
7	3	0.00000	D
6	3	0.00000	D
4	3	0.00000	D
3	3	0.00000	D
2	3	0.00000	D

Means that do not share a letter are significantly different.

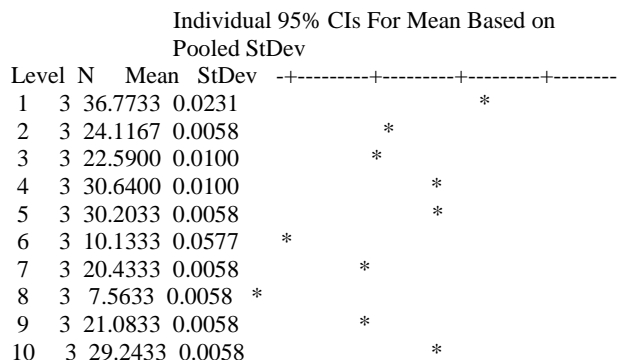
Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Location L

Individual confidence level = 99.80%

One-way ANOVA: Zn versus Location L

Source	DF	SS	MS	F	P
Location L	9	2261.061	251.229	588817.90	0.000
Error	20	0.009	0.000		
Total	29	2261.069			

S = 0.02066 R-Sq = 100.00% R-Sq(adj) = 100.00%



+-----+-----+-----+-----+
 8.0 16.0 24.0 32.0

Pooled StDev = 0.0207

Grouping Information Using Tukey Method

Location L	N	Mean	Grouping
1	3	36.7733	A
4	3	30.6400	B
5	3	30.2033	C
10	3	29.2433	D
2	3	24.1167	E
3	3	22.5900	F
9	3	21.0833	G
7	3	20.4333	H
6	3	10.1333	I
8	3	7.5633	J

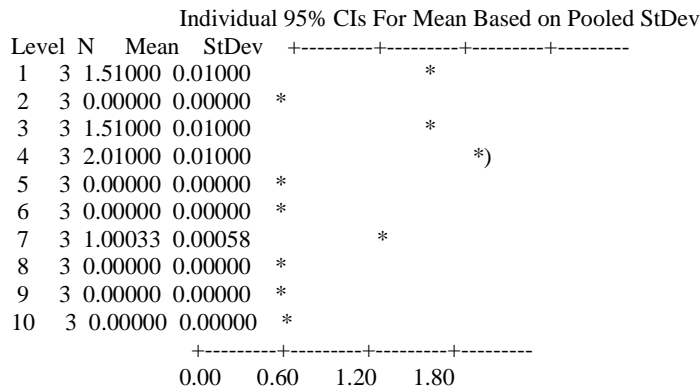
Means that do not share a letter are significantly different.

Tukey 95% Simultaneous Confidence Intervals
 All Pairwise Comparisons among Levels of Location L

One-way ANOVA: Pb versus Location L

Source	DF	SS	MS	F	P
Location L	9	17.89342	1.98816	66198.39	0.000
Error	20	0.00060	0.00003		
Total	29	17.89402			

S = 0.005480 R-Sq = 100.00% R-Sq(adj) = 100.00%



Pooled StDev = 0.00548

Grouping Information Using Tukey Method

Location L	N	Mean	Grouping
4	3	2.01000	A
3	3	1.51000	B
1	3	1.51000	B
7	3	1.00033	C

Tukey 95% Simultaneous Confidence Intervals
 All Pairwise Comparisons among Levels of Location L

Individual confidence level = 99.80%

SOIL Chemical Xteristics

One-way ANOVA: pH versus location

Source	DF	SS	MS	F	P
location	2	0.0134000	0.0067000	201.00	0.000
Error	6	0.0002000	0.0000333		
Total	8	0.0136000			

S = 0.005774 R-Sq = 98.53% R-Sq(adj) = 98.04%

Individual 95% CIs For Mean Based on Pooled StDev

Level	N	Mean	StDev	-----+-----+-----+-----			
1	3	8.96333	0.00577	(--*--)			
2	3	9.03333	0.00577		(--*--)		
3	3	8.94333	0.00577	(--*--)			
				-----+-----+-----+-----			
				8.940	8.970	9.000	9.030

Pooled StDev = 0.00577

Grouping Information Using Tukey Method

location	N	Mean	Grouping
2	3	9.03333	A
1	3	8.96333	B
3	3	8.94333	C

Means that do not share a letter are significantly different.

Tukey 95% Simultaneous Confidence Intervals
 All Pairwise Comparisons among Levels of location

Individual confidence level = 97.80%

One-way ANOVA: EC versus location

Source	DF	SS	MS	F	P
location	2	17480000	8740000	26220000.33	0.000
Error	6	2	0		
Total	8	17480002			

S = 0.5774 R-Sq = 100.00% R-Sq(adj) = 100.00%

Individual 95% CIs For Mean Based on Pooled StDev

Level	N	Mean	StDev	+-----+-----+-----+-----			
-------	---	------	-------	--------------------------	--	--	--

Source	DF	SS	MS	F	P
location	2	385.3030	192.6515	165129.84	0.000
Error	6	0.0070	0.0012		
Total	8	385.3100			

S = 0.03416 R-Sq = 100.00% R-Sq(adj) = 100.00%

Individual 95% CIs For Mean Based on Pooled StDev

Level	N	Mean	StDev	
1	3	22.3067	0.0115	*
2	3	33.2033	0.0058	*
3	3	37.9333	0.0577	*

24.0 28.0 32.0 36.0

Pooled StDev = 0.0342

Grouping Information Using Tukey Method

location	N	Mean	Grouping
3	3	37.9333	A
2	3	33.2033	B
1	3	22.3067	C

Means that do not share a letter are significantly different.

Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of location

Individual confidence level = 97.80%

One-way ANOVA: Bulk De versus location

Source	DF	SS	MS	F	P
location	2	0.0359120	0.0179560	792.18	0.000
Error	6	0.0001360	0.0000227		
Total	8	0.0360480			

S = 0.004761 R-Sq = 99.62% R-Sq(adj) = 99.50%

Individual 95% CIs For Mean Based on Pooled StDev

Level	N	Mean	StDev	
1	3	1.51333	0.00577	(* -)
2	3	1.37933	0.00115	(* -)
3	3	1.51333	0.00577	(* -)

1.400 1.440 1.480 1.520

Pooled StDev = 0.00476

Grouping Information Using Tukey Method

location	N	Mean	Grouping
3	3	1.51333	A
1	3	1.51333	A
2	3	1.37933	B

Means that do not share a letter are significantly different.

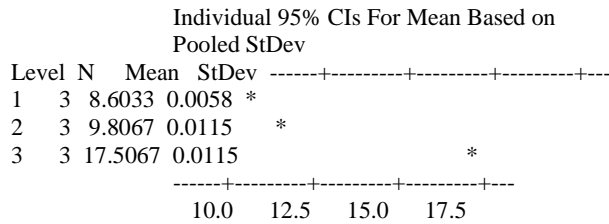
Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of location

Soil Heavy metal concentration

One-way ANOVA: Cu versus location

Source	DF	SS	MS	F	P
location	2	140.0074	70.0037	700036.78	0.000
Error	6	0.0006	0.0001		
Total	8	140.0080			

S = 0.01 R-Sq = 100.00% R-Sq(adj) = 100.00%



Pooled StDev = 0.0100

Grouping Information Using Tukey Method

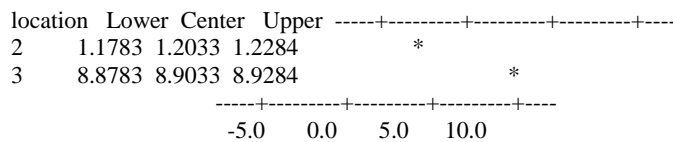
location	N	Mean	Grouping
3	3	17.5067	A
2	3	9.8067	B
1	3	8.6033	C

Means that do not share a letter are significantly different.

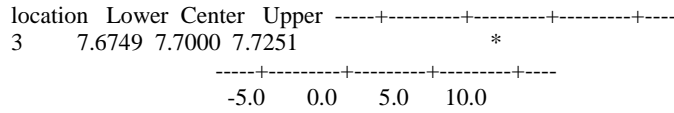
Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of location

Individual confidence level = 97.80%

location = 1 subtracted from:



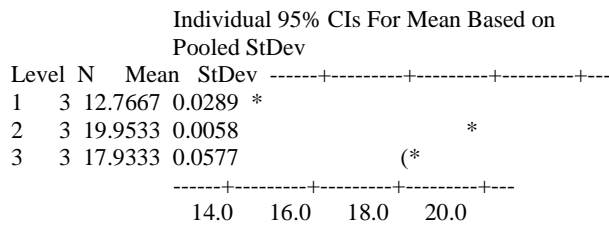
location = 2 subtracted from:



One-way ANOVA: Cr versus location

Source	DF	SS	MS	F	P
location	2	82.42302	41.21151	29436.79	0.000
Error	6	0.00840	0.00140		
Total	8	82.43142			

S = 0.03742 R-Sq = 99.99% R-Sq(adj) = 99.99%



Pooled StDev = 0.0374

Grouping Information Using Tukey Method

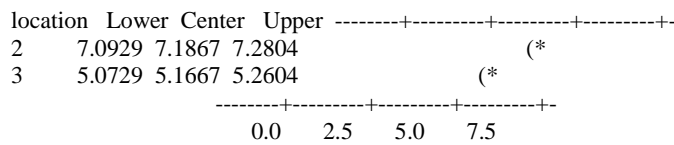
location	N	Mean	Grouping
2	3	19.9533	A
3	3	17.9333	B
1	3	12.7667	C

Means that do not share a letter are significantly different.

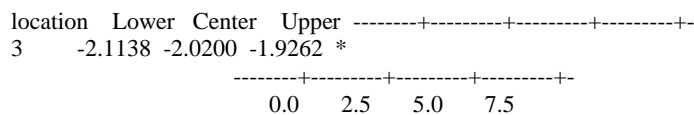
Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of location

Individual confidence level = 97.80%

location = 1 subtracted from:



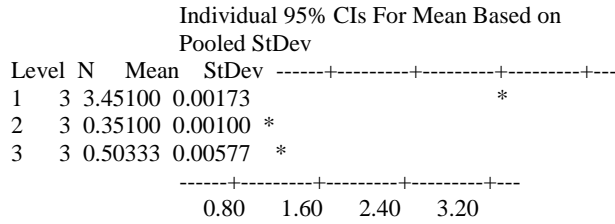
location = 2 subtracted from:



One-way ANOVA: Cd versus location

Source	DF	SS	MS	F	P
location	2	18.32194	9.16097	736149.54	0.000
Error	6	0.00007	0.00001		
Total	8	18.32202			

S = 0.003528 R-Sq = 100.00% R-Sq(adj) = 100.00%



Pooled StDev = 0.00353

Grouping Information Using Tukey Method

location	N	Mean	Grouping
1	3	3.45100	A
3	3	0.50333	B
2	3	0.35100	C

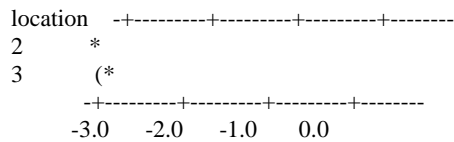
Means that do not share a letter are significantly different.

Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of location

Individual confidence level = 97.80%

location = 1 subtracted from:

location	Lower	Center	Upper
2	-3.10884	-3.10000	-3.09116
3	-2.95651	-2.94767	-2.93883



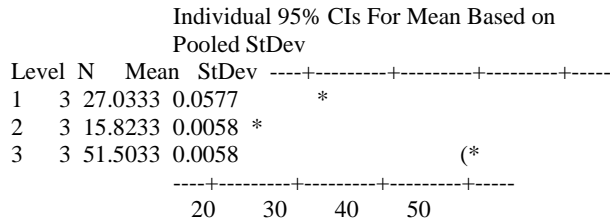
location = 2 subtracted from:

location	Lower	Center	Upper
3	0.14349	0.15233	0.16117

One-way ANOVA: Zn versus location

Source	DF	SS	MS	F	P
location	2	1997.507	998.754	881253.26	0.000
Error	6	0.007	0.001		
Total	8	1997.514			

S = 0.03367 R-Sq = 100.00% R-Sq(adj) = 100.00%



Pooled StDev = 0.0337

Grouping Information Using Tukey Method

location	N	Mean	Grouping
3	3	51.5033	A
1	3	27.0333	B
2	3	15.8233	C

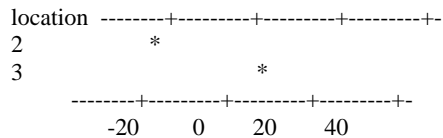
Means that do not share a letter are significantly different.

Tukey 95% Simultaneous Confidence Intervals All Pairwise Comparisons among Levels of location

Individual confidence level = 97.80%

location = 1 subtracted from:

location	Lower	Center	Upper
2	-11.2944	-11.2100	-11.1256
3	24.3856	24.4700	24.5544



location = 2 subtracted from:

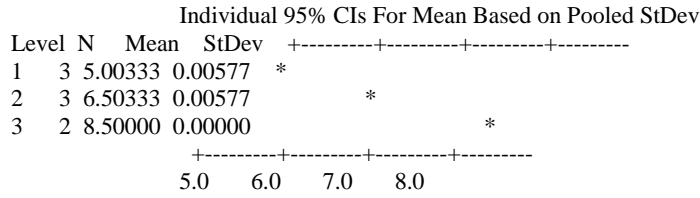
location	Lower	Center	Upper
3	35.5956	35.6800	35.7644

One-way ANOVA: Pb versus location

Source	DF	SS	MS	F	P
location	2	14.69127	7.34563	275461.25	0.000

Error 5 0.00013 0.00003
 Total 7 14.69140

S = 0.005164 R-Sq = 100.00% R-Sq(adj) = 100.00%



Pooled StDev = 0.00516

Grouping Information Using Tukey Method

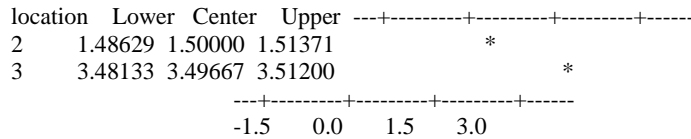
location	N	Mean	Grouping
3	2	8.50000	A
2	3	6.50333	B
1	3	5.00333	C

Means that do not share a letter are significantly different.

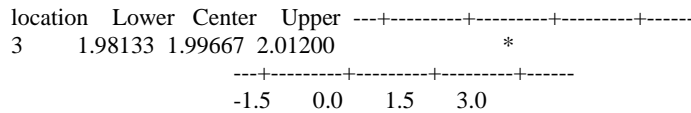
Tukey 95% Simultaneous Confidence Intervals
 All Pairwise Comparisons among Levels of location

Individual confidence level = 97.74%

location = 1 subtracted from:



location = 2 subtracted from:



One-way ANOVA: Fe versus location

Source	DF	SS	MS	F	P
location	2	565.9548	282.9774	202126.70	0.000
Error	6	0.0084	0.0014		
Total	8	565.9632			

S = 0.03742 R-Sq = 100.00% R-Sq(adj) = 100.00%

Individual 95% CIs For Mean Based on Pooled StDev

Level	N	Mean	StDev
1	3	857.693	0.006 *
2	3	875.467	0.029 *
3	3	873.367	0.058 *

-----+-----+-----+-----+-----+-----
860.0 865.0 870.0 875.0

Pooled StDev = 0.037

Grouping Information Using Tukey Method

location	N	Mean	Grouping
2	3	875.4667	A
3	3	873.3667	B
1	3	857.6933	C

Means that do not share a letter are significantly different.

Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of location

Individual confidence level = 97.80%

location = 1 subtracted from:

location	Lower	Center	Upper
2	17.6796	17.7733	17.8671 (*)
3	15.5796	15.6733	15.7671 *

-----+-----+-----+-----+-----+-----
0.0 6.0 12.0 18.0

location = 2 subtracted from:

location	Lower	Center	Upper
3	-2.1938	-2.1000	-2.0062 *)

-----+-----+-----+-----+-----+-----
0.0 6.0 12.0 18.0

Correlations: Cu, Cr, Cd, Zn, Pb, Fe, pH, EC, CEC, total N, TOC, Bulk De

	Cu	Cr	Cd	Zn	Pb	Fe	pH	EC
Cr	0.364							
	0.336							
Cd	-0.569	-0.973						
	0.110	0.000						
Zn	0.906	-0.065	-0.167					
	0.001	0.869	0.668					
Pb	0.950	0.636	-0.796	0.729				
	0.000	0.066	0.010	0.026				
Fe	0.514	0.986	-0.998	0.103	0.756			

	0.157	0.000	0.000	0.792	0.019				
pH	-0.570	0.549	-0.344	-0.861	-0.289	0.404			
	0.109	0.126	0.365	0.003	0.451	0.281			
EC	-0.685	-0.928	0.989	-0.312	-0.878	-0.977	-0.202		
	0.042	0.000	0.000	0.414	0.002	0.000	0.603		
CEC	0.621	-0.503	0.291	0.894	0.347	-0.352	-0.986	0.145	
	0.074	0.167	0.448	0.001	0.360	0.353	0.000	0.709	
total N	0.600	-0.527	0.317	0.882	0.321	-0.378	-0.992	0.172	
	0.088	0.145	0.406	0.002	0.399	0.317	0.000	0.658	
TOC	0.812	0.839	-0.942	0.489	0.953	0.918	0.011	-0.981	
	0.008	0.005	0.000	0.182	0.000	0.000	0.978	0.000	
Bulk De	0.387	-0.715	0.536	0.740	0.082	-0.590	-0.967	0.405	
	0.303	0.030	0.137	0.023	0.834	0.095	0.000	0.280	

	CEC	total N	TOC
total N	0.999		
	0.000		

TOC	0.048	0.021
	0.902	0.958

Bulk De	0.962	0.969	-0.222
	0.000	0.000	0.567

Cell Contents: Pearson correlation
P-Value

Appendix 2



Fluted Pumpkin Farm within Trans/Amadi Industrial layout, Oginigba

Appendix 3



Fluted Pumpkin Farm close to East/West Road, Rukpakwulusi

Appendix 4



Fluted Pumpkin Farm close to Port Harcourt/Aba Expressway, Iriebe