

**POTENTIALLY TOXIC ELEMENTS IN FOOD CROPS
GROWN ON URBAN WASTE DUMP-SITES:
A CASE STUDY OF WAKALIGA DUMP-SITE, KAMPALA CITY, UGANDA**

by
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SCIENCE IN CHEMISTRY**

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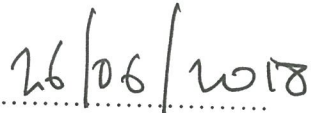
APPROVAL

We affirm that the research work presented in this thesis was carried out by the candidate under our supervision.

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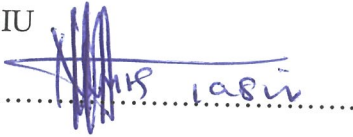
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DECLARATION

I hereby declare that this dissertation - POTENTIALLY TOXIC ELEMENTS IN FOOD CROPS GROWN ON URBAN WASTE DUMP-SITES: A CASE STUDY OF WAKALIGA DUMP-SITE, KAMPALA CITY, UGANDA- is my original work and the results of this study have to the best of my knowledge not been submitted to any other institution of higher learning for an academic award.

NURA TASIU



DEDICATION

This dissertation is dedicated to my late mother, Malama Saratu Mukhtar, as well as to my beloved wife who showed me care and support during my study, and our lovely children Muhammad Daddy and Abubakar Assim.

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LIST OF ACRONYMS

ASTM	American Society for Testing Material
APHA	American Public Health Authority
AAS	Atomic Absorption Spectrophotometer
AB	Absorption
AD	Adsorption
ADI	Acceptable Daily Intake
BDH	British Drugs House
COD	Chemical Oxygen Demand
Cd	Cadmium
Cu	Copper
DPR	Department of Petroleum Resources
D.W	Dry Weight
EPA	Environmental Protection Agency
E.C	Electric conductivity
EC/CODEX	European Council
FAO	Food Agriculture Organization
HCl	Hydrochloric Acid
HNO ₃	Nitric Acid
MCL	Maximum Contaminant Levels
NAFDAC	National Agency for Food Drugs Administration and Control
NEMA	National Emergency Management Agency
PH	Potential Hydrogen
PTE	Potentially Toxic Element
Pb	Lead
SD	Standard Deviation
TF	Transfer Factor
SON	Standard Organization of Nigeria
US	Uganda Standard

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ABSTRACT

This study aimed at investigating the seasonal variation in the levels of contamination in soils, food crops, and domestic spring water samples from Wakaliga dumpsite in Kampala. Potentially Toxic Elements (PTE) and physicochemical properties were analysed during the dry season (May-July 2017) and the wet season (September-November 2017) and the results compared to standard limits set by international and local agencies. The results obtained indicated that some of the elements were found in concentration levels within permissible limits, while others were above permissible set limits in the soil, crops and domestic (spring) water samples. Zinc maximum levels of 3.41 ± 0.01 mg/kg and 3.31 ± 0.04 mg/kg d.w. were found in dry-season picked spinach and sugarcane, respectively, while the lowest concentrations of 0.98 ± 0.02 mg/kg d.w. were found in wet-season cocoyam. Copper was found to exist below permissible limits for all the crops, soil and water; concentrations of lead in spinach were found to be within a permissible limit 2.31 ± 0.005 mg/kg d.w. while all the others were below the permissible limits. Negligible amounts of cadmium were found in all the samples. All the soil samples indicated results below permissible levels of toxic metals in the arable soils as indicated by WHO (1996). The physiochemical parameters were all within acceptable limits for drinking water, as set by WHO and NEMA; Cadmium was not detected in the domestic water. The findings of this research indicated the presence of potentially toxic elements whose levels could be on the increase and found out that zinc concentrations were higher in both crops and soil for both the two harvesting seasons. This was followed by lead, which is attributable to the availability of discarded substances containing these elements in the environment. Proper waste management, control and disposal methods should be put in place to minimize exposure of toxic containing substances into the environment.

CHAPTER ONE

INTRODUCTION

1.1 Background

Our environment is everything around us from the buildings we live into the air we breathe, the water we drink and the food we eat. Ever since human beings have inhabited the earth, they have generated, produced, manufactured, extracted, secreted, discarded and disposed of all kinds of waste (Martin, 2005).

Globalization is not a new phenomenon. However, global connections today differ in at least four important ways from those in the past. First, they function at much greater speed than ever before. Improved technologies enable much faster transportation of people and goods and the instantaneous transmission of information. Second, globalization operates on a much larger scale, leaving few people unaffected and making its influence felt in even the most remote places. Third, the scope of global connections is much broader and has multiple dimensions – economic, technological, political, legal, social and cultural, among others, each of which has multiple facets. Linkages have proliferated to involve multiple, interdependent flows of a greater variety of goods, services, people, capital, information and diseases (UN-Habitat, 2005).

Human activities such as industrial production, mining, agriculture and transportation, release high amounts of toxic metals into surface and ground water, soils, and, ultimately, to the biosphere. Accumulation of toxic elements in crop plants is of great concern due to the probability of food contamination through the soil-root interface. Though the heavy metals like Cd, Pb and Ni are not essential for plant growth, they are readily taken up and accumulated by plants in potentially toxic forms. Ingestion of vegetables irrigated with wastewater and grown in soils contaminated with toxic metals possess a possible risk to human health and wildlife. Heavy

metal concentration in the soil solution plays an important role in controlling metal bioavailability to plants. Most of the studies show that the use of waste water contaminated with heavy metals for irrigation over long period of time increases the heavy metal contents of soils above the permissible limit. Ultimately, increasing the heavy metal content in soil also increases the uptake of heavy metals by plants depending upon the soil type, plant growth stages and plant species (Ruqia *et al.*, 2015).

Urbanization is one of the fastest growing land use transformations. This is occurring everywhere in different cultures, economies, and sizes of the cities and towns. Soon, more than 50% of the world's population will live in or around urban centers (United Nations Human Development Report 1997).

Urbanization in the developing nations of Africa has brought about environmental degradation. Indeed, one of the most pressing concerns of Urbanization in the developing world especially in Africa, has been the problem of solid-liquid and toxic waste management recent events in major Urban centers in Africa have shown that the problem of waste management has become a monster that has aborted most efforts made by the City authorities, State and Federal governments and professionals alike. A visit to any African city today will reveal aspects of the waste management problems such as heaps of uncontrolled garbage, roadsides littered with refuse, streams blocked with junk, disposal sites constituting a health hazard to residential areas and in appropriate disposal of toxic waste (Adepoju, 1999).

Pollutants in the air, water and soil have become more wide-spread in Uganda over the recent past to such an extent that they have now reached detectable levels in a large number of biota including food crops (Nabulo *et al.*, 2008, Mbabazi *et al.*, 2010). This is largely attributed to the rapid national population growth. According to the 1969 national census, the population of

Uganda was at 7 million people, but now in 2014 is estimated at 37 million, an increase of over 500% in 45 years. As a result, more people are migrating to towns and cities owing to land fragmentation in most areas upcountry. (Rusongoza, 2003).

Due to the global rise in human population in many towns and cities Solid waste management has become the biggest challenge facing developing countries where anything that loses value is dumped anywhere without sorting and separation, more problematic than household wastes are the industrial, hospital and institutional waste which often contains hazardous and toxic chemicals, not to mention viruses and bacteria and the so-called heavy metals. These heavy metals need special care when discharging, storing, transporting, and disposing of them. Still, they are allowed to go directly to the water bodies from where they can contaminate the whole water cycle. Or they end up illegally dumped on the streets, open spaces, wastelands, drains or rivers and anywhere they land. Sometimes they are collected to the specific land sites but the protection of water bodies and groundwater is not active (United Nations Habitat, 2004, Ogu 2000).

If solid wastes are left in the open spaces, waste and streets, serious environmental problems will follow. With the rainwater, much of this waste ends up swept into water bodies including receiving rivers. This can lead to the pollution of ground and surface waters because of leaching. Solid wastes are sometimes used for landfill, but decomposed solid waste can similarly pollute groundwater seepage, particularly in humid tropics. This can have enormous health impacts in developing countries where the use of well, springs and river water as drinking water is common. The garbage combustion creates yet another environmental problem, people want to get rid of the waste and they burn them in their backyards. This is a big problem in rapidly growing towns and cities where it is really hard to keep up with the waste production. In the big cities, the daily

amount of waste can be enormous and hard to handle. In lower-income countries the amount of waste is not so big, but the problems have more to do with the collection system. The agencies that are responsible for the collection and disposal of solid waste are often understaffed and underfunded. Also, the lack of equipment, like collection trucks, makes the services inefficient. Because many cities also have poor sanitation, wastes contain a lot of fecal matter. The risk from the uncollected waste is obvious for small children playing in the streets and for waste pickers (Kasarda and Parnell 1993, Habitat 1996).

The gases produced by burning can cause different respiratory diseases. Uncollected waste also spoils the aesthetic outlook of the city (United Nation Habitat 2004, Ogu 2000). Soils are able to biodegrade almost all organic compounds found in waste, converting them into harmless substances. However, inorganic products such as heavy metals are non-biodegradable, and thus they persist and accumulate in the soil and can be absorbed by plants which may finally bioaccumulation in man through the food chain (Fatoki, 2000).

Toxic substances such as metals become more concentrated and potentially more harmful as they move up the food chain known as bioaccumulation. Although essential elements are required by humans for normal metabolisms, most of them may be toxic in levels above the body requirements. The pathologic condition related to metal toxicity results from biochemical (genetic) or physiological environmental abnormality (Robert, 2007). Currently, the various media and modes of exposure include:

Air; Lungs through inhalation of dust metal

Soil or dust; Fumes and vapors

Water; Skin through contact with dust

Biota or food; Mouth by ingestion

The term heavy metal refers to any metallic chemical element that has a relatively high density and is toxic or poisonous at low concentrations (Mbabazi *et al.*, 2010). Examples of heavy metals include mercury (Hg), cadmium (Cd), arsenic (As), chromium (Cr), thallium (Th), and lead (Pb). The use of dumpsites as farm land is a common practice in urban and suburban centers, because of the fact that decayed and composted waste enhance soil fertility. These wastes often contain heavy metal in various forms at different contamination levels. Municipal waste contains such heavy metals like As, Cd, Hg, and Pb, are particularly hazardous to plants, human and animals. Plants grown on such polluted with municipal, domestic, or industrial waste can absorb heavy metals in the form of mobile ions present in the soil through their roots, or through foliar absorption. These absorbed metals get bioaccumulated in roots, stems, fruits, grains, and leaves of plants (Opaluwa *et al.*, 2012).

In Uganda, it is a usual practice to find vendors, hawkers and some women in markets selling food and vegetable crops like beans, sugar cane, bananas, spinach(dodo) in order to raise income to sustain their families. Where these crops are grown in villages in specified gardens free from waste contamination and the rest are picked from such waste dump sites located in wetlands in towns and city centers. There is no clear distinction between the crops picked from such wet lands and those from gardens located far away from the pollution of the cities and towns. They end up mixing and selling them to different people around towns including unmindful passer-by city and town dwellers who have no clear knowledge about their source of origin and composition. Studies have shown that heavy metals from these wastes can accumulate in the soils at toxic levels hence the risk of crops grown in these areas getting contaminated with heavy metals and consequently endangering human health (Twinamatsiko *et al.*, 2016).

Severe effects of heavy metals include reduced growth and development, cancer, organ damage, nervous system damage and in extreme cases death. Exposure to some metals, such as mercury and lead, may also cause the development of autoimmunity, in which a person's immune system attacks its own cells. This can lead to joint diseases such as rheumatoid arthritis, and diseases of the kidney, circulatory, and nervous system (Mbabazi *et al.*, 2010).

In Kampala city alone, domestic waste generation is estimated to range between 0.2 metric tones per person annually on average (Ngategize *et al.*, 2001), therefore considering an urban population of 3.7 million people that is 13.4 % of the population of Uganda (Uganda Population Secretariat, 2007). It means that approximately 740,000 metric tons of waste were generated in urban areas per year. (Natamba, 2011).

Wakaliga consists of 100 square meters of farms at which the local people use to grow some food crops in and around the field. This area has been a dumping land for so long, but due to land shortage in the city, people have started utilizing this land for construction and even agriculture because it is believed to be fertile because of decomposition of waste matter. It is also waterlogged with many water streams and water bodies like springs do exist from which people fetch their water. This water is also likely to be contaminated with these waste materials. Therefore, this study was carried out to investigate the levels of these heavy metals in the soil, food crops and the spring water around this field. When Kampala started to develop into a major urban center, around the 1960s, Kampala City Council (KCC) has been dumping its waste in Wakaliga valley over and above some of the domestic water sources. With time people started to grow crops on the dumpsite, not only growing crops but also made it a place for human settlement.

1.2 Problem Statement

In developing countries like Uganda, waste disposal and management is still poor, as anything that loses value is dumped into the environment without sorting and separation. When it rains, all these wastes (industrial, domestic, and municipal) are flushed into runoffs and find their way into low lying areas and water channels. It is around these water channels that agriculture is normally practiced because these areas are believed to be fertile though rich in potentially toxic element. Plants grown in heavy metal contaminated soils can also take up these heavy metals which are in high concentrations (Nabulo, 2004). This has created a lot of fears that the potentially toxic element concentration in these plants might exceed the safe and permissible limits sets by (WHO 1996).

Therefore, pollution of water, soils and plants by potentially toxic elements may eventually enter the food chain through such crops and end up in our food menu that is consumed by the urban population, which courses many dangerous diseases such as kidney, liver damages, cancer, nervous system damage, cardiovascular diseases, pregnancy loss, child defects among others, and should therefore be investigated, hence this study.

1.3 Objectives

1.3.1 General objective

The general objective of this study was to investigate the effects of potentially toxic elements (Zinc, Cadmium, Lead and Copper) in food crops grown on dumpsite soils and spring water, in Wakaliga, a Kampala suburb.

1.3.2 Specific objectives

1. To determine the level of accumulation of the selected potentially toxic elements in food crops, soils and water from the study area.

2. To quantify and compare the levels of potentially toxic elements in soils, water and food crops with minimum standards, set by national and international regulatory bodies. Like WHO, NEMA US, UNBS.
3. To determine the physicochemical parameters of spring water around Wakaliga.

1.4 Scope

1.4.1 Content scope

This study investigated the levels of the potentially toxic elements in the soil, food crops, and some of the physiochemical parameters of spring water around this field. The study focused on four potentially toxic metals, namely copper (Cu) cadmium (Cd), zinc (Zn) and lead (Pb). This is because cadmium poses a great health risk to human beings even at very low concentrations in the body and because the body has limited capacity to respond to cadmium exposure, as the metal cannot undergo metabolic degradation to less toxic species and is poorly excreted. Lead is one of the major components of fuel and highly present in car batteries and paint, and it is therefore expected to be present in high amounts in such food crops grown in contaminated areas these two metals, cadmium and lead, have no any physiological role they play in our body apart from causing harm to human beings. And these are among the most common components of waste especially domestic waste, from discarded car batteries, dry cell batteries, paint, polyvinyl pipes old vehicle tires, run offs from corroded iron sheets, oil spills motor vehicle garage from car washing sites among others. The study relied on strict minimum standard set by NEMA, WHO/FAO, NAFDAC, US, among others as our control experiment and for comparisons purposes.

1.4.2 Geographical Scope

The study was conducted at Wakaliga dumpsite field an area within Rugaba division in Kampala City which is 9 km from the city center.

1.4.3 Time Scope

The study was conducted between the dry season, (May to July 2017), and the wet season (September to November 2017). The dry and wet seasons were expected to give the maximum and minimum levels of the metals concentrations.

1.5 Significance of the study

1. Government at all levels: Various ministries will benefit from this study. For instance, Ministries of environment, and Health will benefit from the study by implementing policies and laws that can reduce and regulates the number of toxic or potentially toxic substances discarded directly to the environment the Ministry of Land and Urban Planning will use the information from the study to halt the use of such dumpsites as farms. Ministry of agriculture will use the information from the study to expose urban farmers to new and less toxic agricultural practices, like vertical farming. The government will make more policies concerning waste disposal.
2. Health: The study provides useful information to authorities in the health sector (Hospitals and Diseases control centers) to know the origins and occurrences of some certain long-term diseases, or undetected for long-term, such as cancer. The study will provide useful information on metal toxicity in low concentration, and higher concentrations, in food and water contaminations.
3. Non-Governmental Organizations (NGOs): Non-Governmental Organizations; The study will help to frame policy and enlighten government and the general public on how to go about new and modern farming. NGOs will use the information from this study to help the public to control and tackle metal toxicity.
4. General Public that Uses such crops: The study will expose the danger which people are subjected to by eating the food crops grown on such farms. This can be done by intensive

public enlightenment campaign using print, audio-visual media, posters among others.

The study will help and guide the general public about ways of reducing and recycling the toxic substance before disposing into the environment. The study will also inform the general public about new technology on modern farming and irrigations systems, that require less water and of less toxic to human consumption. Such as vertical farming.

5. The body of scientific knowledge: Finally, the study will add to the body of knowledge already generated in related studies and will be utilized by future researchers on the related research problems.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

World's urban communities are increasing faster than the global population as the urbanization progresses in the least-developed regions (United Nation - Habitat, 2004). Urban development caused momentous alteration to the environment by increasing the waste material accumulation through anthropogenic activities (Chen, 2007). Urban expansion is promoting a concern for farmers to use contaminated lands for food crop's production (Nabulo, 2009).

In urban and peri-urban areas, land contamination with toxic metals is common as a result of the industrial and municipal activity. Wastewater irrigation to increase the yield of food crops (vegetables) is the principal source of contamination in urban agricultural lands (Qadir *et al.*, 2000). These effluents are rich in toxic metals and are a chief contributor to metals loading in waste irrigated and amended soils (Singh *et al.*, 2004 and Mapanda *et al.*, 2005).

Soil contaminated with metals is a primary route of toxic element exposure to humans. Toxic metals can enter the human body by consumption of contaminated food crops, water or inhalation of dust (Cambra *et al.*, 1999). It has been estimated that more than 70% of the dietary intake of cadmium is contributed via food chain (Wagner, 1993). Vegetables grown on contaminated land may accumulate toxic metals. Prolonged consumption of contaminated foodstuff may lead to the unceasing accumulation of toxic metals in the liver and kidney of humans resulting in the disturbance of biochemical processes, leading to malfunctioning of liver, kidney, cardiovascular, nervous and bone disorders (Jarup 2003, and WHO, 1992).

Heavy metal ingestion through food chains is injurious to human health (Jarup, 2003). When consumed they end up entering the food chain and subsequently exhibit toxicological effects in

humans (Mugabe *et al.* 1998, Ssebagala *et al.*, 2004). They affect organs like the brain, kidney, liver, intestinal tract and lungs.

These heavy metals are extremely resistant to changes that would otherwise lead to their partial or complete elimination from the environment (Mbabazi *et al.*, 2010). They undergo biogeochemical cycles; their potential toxicity is controlled mainly by their physicochemical modifications. They have a tendency to accumulate in vital human organs (Chen *et al.*, 2010).

(Alloway 1996) observed that heavy metal absorption by crops depends on their concentration in the soil, intermetal inhibition factors like Zinc, and Copper, cation exchange ratio and other factors like pH that determine the bioavailability of metals. Soils are able to biodegrade almost all organic compounds found in waste, converting them into harmless substances. However, inorganic products such as heavy metals are non-biodegradable. Thus they persist and accumulate in the soil and can be absorbed by plants which may finally bioaccumulate in man through food chain (Fatoki, 2000). At the same time if these plants decay these toxic metals are redistributed and as a consequence, their enrichment in the agricultural soils occurs.

Bioaccumulation, geo accumulation, biomagnifications and translocation may result because of the entrance of these heavy metals into the ecosystem.

Some heavy metals such as copper, selenium, and zinc are essential in maintaining the metabolism of the human body, but are toxic at high concentrations; they become dangerous in such a way that they tend to bioaccumulate and the process of their storage in the body is faster than their metabolism. Good heavy metals become toxic to our bodies when consumed in large amounts and it takes really very little time to be too much and on top of that more than twenty heavy metals that we take including lead and cadmium are non-essential for our health functioning (www.globalhealing).

Unlike developed countries, it is difficult to estimate the level of health hazard from heavy metals in the urban environment in developing countries because urban farming is usually unregulated and soils are rarely tested (Nabulo, 2004). There tends to be little awareness among farmers or consumers about the health implications of heavy metals and pathogens, or guidance to farmers.

Heavy metal concentrations in urban areas of less industrialized countries are generally far lower than those in industrial countries. However, there are specific areas that pose a health threat. There is very little data on the health impact of heavy metals in cities in developing countries, or the contribution of urban farming to this health problem (Nriagu, 1988). There exists a global need to identify vulnerable areas and regulate farming in these locations to ensure food safety.

Health risk assessment of heavy metals in contaminated vegetables is being carried out in developed countries (Milacic and Kralj, 2003); however, little is explored in developing countries (Lock and de Zeeuw, 2001). Environmental abatement practice is almost missing due to the lack of environmental management and un-operational environmental pollution laws.

2.2 Potentially Toxic Elements (PTEs)

Potentially toxic elements (PTE's) The heavy metals are typically identified as Zinc (Zn), Copper (Cu), Nickel (Ni), Cadmium (Cd), Lead (Pb), Mercury (Hg), Chromium (Cr), Molybdenum (Mo), Selenium (Se), Arsenic (As) and Fluoride (F). These elements occur naturally in many soils, in different concentrations but the most concern is about the accumulation of these elements in soils by the addition of manures, slurries and waste products.

2.2.1 Zinc

Zinc is a metal that belongs to group IIB of the periodic table. Zinc metal does not occur in the natural environment. It is present only in the divalent state Zn (II). Total Zn content of soils is largely dependent on the composition of the parent rock material (Kabata-Pendias, 1984). Zinc is an essential element for all living organisms. It is necessary and indispensable for human, animal and plant life. An optimal zinc availability range exists for each living organism. Within this concentration range, animals and plants can regulate their internal zinc concentration to meet their metabolic needs.

2.2.2 Occurrence of zinc

Zinc is able to form complexes with a variety of organic ligands. Plant availability of zinc is affected by mainly soil parameters such as soil pH, organic matter adsorption sites, microbial activity and moisture zinc taken up by plant roots is mainly in the form of Zn^{2+} ions and in forms such as hydrated zinc complexes and zinc organic chelates (Kabata-Pendias, 1984)

2.2.3 Uses of zinc

Zinc is an essential trace element, necessary for plant, animals and microorganisms (Prasad, 2008, Broadley *et al.*, 2007) Zinc Serves as structural ions in transcription factors and is stored and transferred in metallothioneins. It is typically the second most abundant transition metal in organisms after iron and it is the only metal which appears in all enzyme classes (Broadley *et al.*, 2007). In proteins, Zn ions are often coordinated to the amino acid side chains of aspartic acid, glutamic acid, cysteine and histidine. The theoretical and computational description of this zinc binding in proteins (as well as that of other transition metals) is difficult (Brandt *et al.*, 2009).

2.2.4 Zinc pollution

The main anthropogenic sources of soil contamination by zinc are mining, zinc production facilities, iron and steel production, fuel combustion. The other sources are fertilizers and pesticides, atmospheric fallout, disposal of zinc-containing wastes such as agricultural and animal wastes, manure and sewage sludge (Nriagu and Pacyna, 1988) other sources of zinc pollution are corrosion of galvanized structures and water pipes, cosmetics and pharmaceuticals.

2.2.5 Zinc Toxicity

Although zinc is an essential requirement for good health, excess zinc can be harmful. Excessive absorption of zinc suppresses copper and iron absorption (Fosmire, 1990). The free zinc ion in solution is highly toxic to plants, invertebrates, and even vertebrate fish (Ronald, 1993). The free zinc ion is a powerful Lewis acid up to the point of being corrosive. Stomach acid contains hydrochloric acid, in which metallic zinc dissolves readily to give corrosive zinc chloride. Swallowing a post-1982 American one cent piece (97.5% zinc) can cause damage to the stomach lining due to the high solubility of the zinc ion in the acidic stomach (Bothwell *et al.*, 2003).

The U.S. Food and Drug Administration (FDA) has stated that zinc damages nerve receptors in the nose, which can cause anosmia. Reports of anosmia were also observed in the 1930s when zinc preparations were used in a failed attempt to prevent polio infections. (Oxford and Oberg, 1985) On June 16, 2009, the FDA said that consumers should stop using zinc-based intranasal cold products and ordered their removal from store shelves. The FDA said the loss of smell could be life-threatening because people with impaired smell cannot detect leaking gas or smoke and cannot tell if food has spoiled before they eat it. Recent research suggests that the topical antimicrobial zinc pyrithione is a potent heat shock response inducer that may impair genomic integrity with induction of PARP-dependent energy crisis in cultured human keratinocytes and melanocytes (Lamore *et al.*, 2010).

Although maximum Zn tolerance for human health has been established for edible parts of crops (20 mg/kg) (Chinese Department of Preventive Medicine, 1995), soil Zn threshold for producing safe vegetables is not available.

2.3 Cadmium

2.3.1 Occurrences

Cadmium is a chemical element with symbol Cd has atomic number 48. This soft bluish-white metal is chemically similar to the two other stable metals in group 12, zinc and mercury. Like zinc, it demonstrates oxidation state of +2 in most of its compound and like mercury, it has a lower melting point than the transition metals in group 3 through 11. Cadmium and its congeners in group 12 are often not considered transition metals, in that they do not have partly filled d or f electron shells in the elemental or common oxidation states. The average concentration of cadmium in Earth's crust is 0.1 and 0.5 (ppm) it was discovered in 1817 simultaneously by Stromeyer and Hermann, both in Germany, as an impurity in zinc carbonate. Cadmium was used for a long time as a corrosion-resistant-plating on steel. Cadmium use is generally decreasing because it is toxic EU. Specifically listed it in the list of restricted hazardous substances.

Cadmium occurs as a minor component in most zinc ores and is a by-product of zinc production. Cadmium makes up about 0.1 mg/kg^{-1} (ppm) of Earth's crust. Cadmium is produced mainly as a by-product from mining, smelting, and refining sulfidic ores of zinc, and to a lesser degree lead and copper (Marrow, 2010).

2.3.2 Uses

Cadmium is used in batteries, paint pigment and motor vehicle tires as the treads wear down, cadmium is released on the streets. Cadmium is used as a coating for metals in electroplating to prevent corrosion. Cadmium is also used in DDT pesticides and Dioxin manufacture (John and Doris 2001). Cadmium compounds are also used as red, orange pigments to colour glass and to

stabilize plastics. Another new use of cadmium is cadmium telluride solar panels (Marrow, 2010).

2.3.3 Toxicity

Cadmium is a heavy metal classified as a group one carcinogen (IARC 1993) affecting multiple systems in humans and animals. Exposure to cadmium occurs primarily through ingestion of contaminated water, food and to a significant extent through inhalation and cigarette smoking. Cadmium poisoning came into prominence with the infamous Itai-Itai disease of the 1960s in Japan after ingestion of cadmium-contaminated rice. Cadmium has a long biological half-life (20 years) and primarily affects the kidneys, liver and intestine, while a prolonged exposure has proven to be carcinogenic to liver, kidney, and lungs, prostate, hematopoietic and other systems. In this regard, cadmium has been classified as a carcinogen (Angshuman *et al.*, 2013).

Cadmium can also accumulate in the pancreas, lungs, central nervous system and testes in men. Cadmium particles are transported along primary olfactory neurons to their terminations in the olfactory bulb. Some other metals, such as manganese, do migrate further into the brain, unlike cadmium which accumulates in the olfactory bulb (Sunderman, 2001).

2.3.4 Exposure

Cadmium poses a great health risk to humans even at very low concentrations in the body and because the body has limited capacity to respond to cadmium exposure, as the metal cannot undergo metabolic degradation to less toxic species and is poorly excreted (Waalkes, 2003). The target organs for cadmium toxicity in animals include the liver, kidney, lungs, testes, prostate, heart, skeletal system, nervous system and immune system. Symptoms of acute cadmium poisoning usually appear after 24 hours and they include shortness of breath, general weakness, fever. It can also cause pulmonary edema, pneumonia, and in severe cases, respiratory failure and death (Järup *et al.*, 1998).

Women have higher cadmium body burden than men, reflected as higher concentrations of cadmium in blood, urine and kidney cortex (Vahter *et al.*, 2007) and (Jarup, 2009). The main reason for the higher body burden in women is increased intestinal absorption of dietary cadmium (Berglund *et al.*, 1994).

2.3.5 Copper

2.3.5.1 Occurrences

Copper, a reddish coloured metal, is a relatively rare element, accounting for only 0.0068% of the earth's crust by mass (John *et al.*, 2001).

Copper is found mainly as the sulphide, oxide or carbonate, its major ores being copper pyrite (chalcopyrite), CuFeS_2 , which is estimated to account for about 50% of all copper deposits. Copper glance (chalcocite), Cu_2S , cuprite, Cu_2O and malachite, $\text{Cu}_2\text{CO}_3(\text{OH})_2$ in large amounts are found in various part of the world.

2.3.5.2 Uses

A human adult contains around 100mg of copper, mostly attached to a protein, an amount exceeded only by iron and zinc among transition metals and requires a daily intake of some 3-5mg. Copper deficiency result in anaemia, and the congenital inability to excrete Cu resulting in its accumulation is Wilson's disease (Greenwood and Eanshaw, 1986).

Copper appears in electrical wires, pipes in combination with other metals to form alloys, as a mildew inhibitor, and as a wood and leather preservatives.

Copper is an essential trace element that is required for the plant, animal, and human health. It is also required for the normal functioning of aerobic (oxygen-requiring) microorganisms.

2.3.5.3 Toxicity

When insufficient quantities of copper are ingested, copper reserves in the liver will become depleted and resulting into copper deficiency leading to disease or tissue injury and in extreme cases, death. Toxicity from copper deficiency can be treated with a balanced diet or supplementation under the supervision of a doctor. On the contrary, like all substances, excess copper intake at levels far above World Health Organization limits can become toxic. All animals need a certain amount of copper. Copper toxicity is mostly associated with grazing animals, where luxury Cu uptake by grass plant can create toxic swards for grazing animals. In humans, it is associated with blood problems and organ dysfunction.

2.4 Copper Exposure.

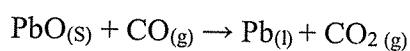
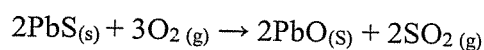
Concentration amount far above trace levels can produce respiratory and gastrointestinal disturbances. Very high levels are known to cause liver damage, renal damage and death. Copper exposure occurs by inhalation, ingestion of containing foods and water and direct with skin. Small amounts of copper may dissolve into the water from copper piping concentration when the water remains in the pipes overnight. Copper, zinc and iron are essential for human nutrition but can be toxic if ingested in excess amount (Revert, 2007).

2.4.1 Lead

Lead is relatively uncreative post-transition metal. Its weak metallic character is illustrated by its amphitricha nature; lead and lead oxides react with acids and bases and they tend to form covalent bonds. Compounds of lead are usually found in the +2-oxidation state rather than the +4 common with higher members limited to organized compounds. Lead is a heavy, very soft, highly malleable, bluish- grey metallic element most lead is used as the metal (Maria 1994).

2.4.2 Occurrence

Lead is the most common of the heavy metals and occurs naturally in soils. It is known to cause problems with the blood, including anaemia. It is also associated with gastrointestinal and cardiovascular problems. Lead is obtained from its ore, galena (PbS) by roasting the sulphide in the air and reducing the resulting PbO with carbon monoxide in a blast furnace (John *et al.*, 2001).



2.4.3 Uses

Sources of environmental lead include lead gasoline, tap water soldered pipes, and painted surfaces in older buildings. Lead can be found as metals oxides, nitrates, and sulphides, leads for buildings, paint glaze, glass, in batteries and in fuels.

2.4.4 Lead Toxicity

As heavy metal lead is ubiquitous in our environment but also has no physiological role in the biological system. Lead toxicity is a particularly insidious hazard with the potential for causing irrepressible health effects. It interferes with a number of body functions primarily affecting the central nervous, hematopoietic, hepatic and renal system producing serious disorders (Murata *et al.*, 2009). The greatest public health issue related to lead at present is exposure of young children to a decaying fragment of leaded paints. (Berg, 2009).

Compared with adult lead poisoning paediatric lead poisoning is a somewhat problem. First reported in the late 1800s in Australia. It should be noted that toxic metals including lead, can be transmitted from a mother to her child via breast milk. Lead poisoning is probably the most important chronic environmental illness affecting modern children. Incidence serious cases of

lead poisoning still appear in hospital emergency department, clinics and private physician's offices. In children virtually, no organ system is immune to the effects of lead poisoning (Rebelo and Acaldas, 2016).

2.4.5 Effects of potentially toxic elements (PTEs) on the soil

Heavy metals indirectly affect soil enzymatic activities by shifting the microbial community which synthesizes enzymes (Nabulo, 2009). Heavy metals cause a decrease in bacterial species richness and a relative increase in soil actinomycetes or even decreases in both the biomass and diversity of the bacterial communities in contaminated soils (Chen *et al.*, 2010).

Soils polluted with heavy metals have become common across the globe due to increasing ecological and anthropogenic activities. Although heavy metals are naturally present in the soil geological and anthropogenic activities increase the concentration of these elements to amounts that are harmful to both plants and animals. Some of these activities include mining and smelting of metals, burning of fossil fuels, use of fertilizers and pesticides in agriculture, production of batteries and other metal products in industries, sewage sludge, and municipal waste (Chibuke and Obiora, 2014).

Soil properties affect metal availability in diverse ways. Soil pH is the major factor affecting metal availability in soil. Availability of Cd and Zn to the roots of the decreased with increases in soil pH. Organic matter and hydrous ferric oxide have been shown to decrease heavy metal availability through immobilization of the metals. Significant positive correlations have also been recorded between heavy metal and some soil physical properties such as moisture content and water holding capacity (Chibuke and Obiora, 2014).

Other factors that affect the metal availability in soil include the density and type of charge in soil colloids, the degree of complexation with ligands, and the soil's relative surface area

(Marques *et al.*, 2009). The large interface and specific surface areas provided by soil colloids, help in controlling the concentration of heavy metals in natural soils. In addition, soluble concentrations of metals in polluted soils may be reduced by soil particles with the high specific surface area, though this may be metal specific. For instance, McBride and Martínez (1984) reported that addition of amendment consisting of hydroxides with high reactive surface area decreased the solubility of As, Cd, Cu, Mo, and Pb while the solubility of Ni and Zn was not changed. Soil aeration, microbial activity, and mineral composition have also been shown to influence heavy metal availability in soils (Magnuson *et al.*, 2001).

2.4.6 Effects of potentially toxic elements (PTEs) on Plants

Some of these heavy metals such as As, Cd, Hg, Pb or Se are not essential for plant growth since they do not perform any known physiological function in plants. Others like Co, Cu, Fe, Mn, Mo, Ni and Zn are essential elements required for normal growth and metabolism of plants, but these elements can easily lead to poisoning when their concentration is greater than optimal values (Long, 2003). Absorption and accumulation of heavy metals in plant tissue depend upon many factors which include temperature, moisture, organic matter, pH and nutrient availability. Heavy metal accumulation in plants depends upon plant species and the efficiency of different plants in absorbing metals is evaluated by either plant uptake or soil to plant transfer factors of the metals (Karanja *et al.*, 2010).

Growth reduction as a result of changes in physiological and biochemical processes in plants growing on heavy metal polluted soils has been recorded. The continued decline in plant growth reduces yield which eventually leads to food insecurity (Chibuke and Obiora, 2014).

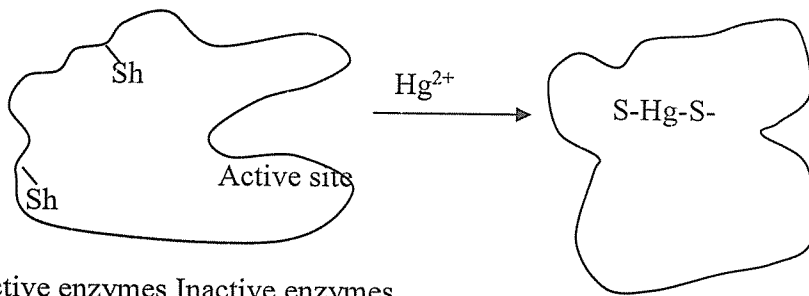
The heavy metals that are available for plant uptake are those that are present as soluble components in the soil solution or those that are easily solubilized by root exudates. Although plants require certain heavy metals for their growth and upkeep, excessive amounts of these

metals can become toxic to plants. The ability of plants to accumulate essential metals equally enables them to acquire other non-essential metals (Djingoba and Kuleff, 2000). As metals cannot be broken down, when concentrations within the plant exceed optimal levels, they adversely affect the plant both directly and indirectly.

The effect of heavy metal toxicity on the growth of plants varies according to the particular heavy metal involved in the process. For metals such as Pb, Cd, Hg, and As which do not play any beneficial role in plant growth, adverse effects have been recorded at very low concentrations of these metals in the growth medium (Chibuke and Obiora, 2014).

2.4.7 Factors that affect the rate of heavy metal uptake by plants

Mench *et al.* (1994) found out that the transfer ratios of Cd, Hg, Cu and Zn, and to some degree Pb and Fe, in plants from the background soils with lower concentrations of the metals were higher than those from the refuse dump soils with higher metal loads. This indicated that some soil factors apart from the total soil content of the metals also affect the rate of metal uptake by plants. The application of some materials as dolomite, phosphates or organic matter into soils was found to reduce the concentration of metals by precipitation, adsorption, or complexation and thereby to make them unavailable to plants. According to Rieuwerts *et al.*, (1998) total concentration of Cd, Cu, Pb and Zn in soils depend on a number of factors which includes, cations, exchange, specific absorption, precipitation, complexation, pH, Redox potential, soil texture, clay content, organic matter content among others. Heavy metals especially those near the bottom of the periodic table exert their action primarily by inactivating enzymes. Heavy metal ions react with hydrogen sulphide to form insoluble sulphides. Most enzymes have amino acids with sulfhydryl (-SH) groups. Heavy metal ion tie up these groups, rendering the enzymes inactive. (John and Doris, 2001)



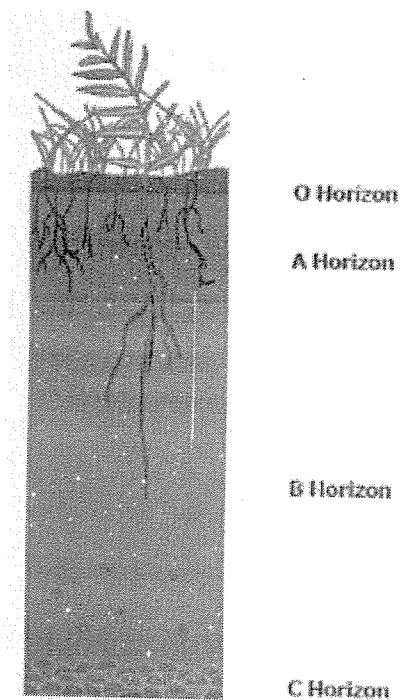
Active enzymes Inactive enzymes

2.4.8 Soils and Soil Texture

The soil is the thin layer of material covering the earth's surface and is formed from the weathering of rocks. It is made up mainly of mineral particles, organic materials, air, water and living organisms—all of which interact slowly yet constantly.

Most plants get their nutrients from the soil, and they are the main source of food for humans, animals and birds. Therefore, most living things on land depend on soil for their existence.

The soil is a valuable resource that needs to be carefully managed as it is easily damaged, washed or blown away. If we understand soil and manage it properly, we will avoid destroying one of the essential building blocks of our environment and our food security.



Soil profile showing the different layers or horizons.

Figure 1: The soil profile showing soil horizons

As soils develop over time, layers (or horizons) form a soil profile. Most soil profiles cover the earth as 2 main layers topsoil. Soil horizons are the layers in the soil as you move down the soil profile. A soil profile may have soil horizons that are easy or difficult to distinguish.

A horizon humus-rich topsoil where nutrient, organic matter and biological activity are highest (i.e., most plant roots, earthworms, insects and micro-organisms are active). The A horizon is usually darker than other horizons because of the organic materials. B horizon—clay-rich subsoil. This horizon is often less fertile than the topsoil but holds more moisture. It generally has a lighter colour and less biological activity than the A horizon. Texture may be heavier than the A horizon too. C horizon—underlying weathered rock (from which the A and B horizons form).

Some soils also have an O horizon mainly consisting of plant litter which has accumulated on the soil surface. The properties of horizons are used to distinguish between soils and determine land-use potential.

2.4.9 Springwater

A spring is any natural situation where water flows from an aquifer to the Earth's surface. It is a component of the hydrosphere. On an average day nearly 303 million US gallons (1,150,000 m³) of water flow from Big Spring in Missouri at a rate of 469 cubic feet per second (13.3 m³/s). A spring may be the result of karst topography where surface water has infiltrated the Earth's surface (recharge area), becoming part of the area groundwater. The groundwater then travels through a network of cracks and fissure openings ranging from intergranular spaces to large caves. The water eventually emerges from below the surface, in the form of a karst spring. The forcing of the spring to the surface can be the result of a confined aquifer in which the recharge area of the spring water table rests at a higher elevation than that of the outlet. Spring water forced to the surface by elevated sources are artesian wells. This is possible even if the outlet is in the form of a 300-foot-deep (91 m) cave. In this case, the cave is used as a hose by the higher elevated recharge area of groundwater to exit through the lower elevation opening.

Non-artesian springs may simply flow from a higher elevation through the earth to a lower elevation and exit in the form of a spring, using the ground like a drainage pipe.

Still, other springs are the result of pressure from an underground source in the earth, in the form of volcanic activity. The result can be water at an elevated temperature such as a hot spring.

The action of the groundwater continually dissolves permeable bedrock such as limestone and dolomite, creating vast cave systems.

2.5 Types of spring water

Seepage or filtration spring. The term seep refers to springs with small flow rates in which the source water has filtered through permeable earth.

Fracture springs, discharge from faults, joints, or fissures in the earth, in which springs have followed a natural course of voids or weaknesses in the bedrock.

Tubular springs, in which the water flows from underground caverns.

2.5.1 Flow of spring water

Spring discharge, or resurgence, is determined by the spring's recharge basin. Factors that affect the recharge include the size of the area in which groundwater is captured, the amount of precipitation, the size of capture points, and the size of the spring outlet. Water may leak into the underground system from many sources including permeable earth, sinkholes, and losing streams. In some cases, entire creeks seemingly disappear as the water sinks into the ground via the stream bed.

2.5.2 Classification of spring water

Springs are often classified by the volume of the water they discharge. The largest springs are called "first-magnitude", defined as springs that discharge water at a rate of at least 2800 litres or 100 cubic centimetres.

2.5.3 Springwater content

Minerals become dissolved in the water as it moves through the underground rocks. This may give the water flavour and even carbon dioxide bubbles, depending on the nature of the geology through which it passes. This is why spring water is often bottled and sold as mineral water, although the term is often the subject of deceptive advertising. Springs that contain significant

amounts of minerals are sometimes called 'mineral springs'. (Springs without such mineral content, meanwhile, are sometimes distinguished as 'sweet springs'.) Springs that contain large amounts of dissolved sodium salts, mostly sodium carbonate, are called 'soda springs'. Many resorts have developed around mineral springs and are known as spa towns.

Water from springs is usually clear. However, some springs may be coloured by the minerals that are dissolved in the water. For instance, water heavy with iron or tannins will have an orange colour.

2.5.4 Uses of spring water

Springs have been used for a variety of human needs including drinking water, domestic water supply, irrigation, mills, navigation, and electricity generation. Other modern uses include recreational activities such as fishing, swimming, and floating; therapy; water for livestock; fish hatcheries; and supply for bottled mineral water.

2.5.5 Sacred springs

A sacred spring, or holy well, is a small body of water emerging from underground and revered either in a Christian, pagan or another religious context, sometimes both. The lore and mythology of ancient Greece were replete with sacred and storied springs—notably, the Corycian, Pierian and Castalian. In medieval Europe, holy wells were frequently pagan sacred sites that later became Christianized. The term "holy well" is commonly employed to refer to any water source of limited size (i.e., not a lake or river, but including pools and natural springs and seeps), which has some significance in local folklore. This can take the form of a particular name, an associated legend, the attribution of healing qualities to the water through the numinous presence of its guardian spirit or Christian saint, or a ceremony or ritual centered on the well site.

In Christian legend, the spring water is often said to have been made to flow by the action of a saint, a familiar theme especially in the hagiography of Celtic saints (UGSS, 2009).

2.6 The intolerable daily intake approach

In order to avoid undesirable health effects as a result of excessive intake of toxicant including toxic metals, international and national scientific organizations such as FAO/WHO, FDA, European Union, among others have used the safety factor approach for establishing acceptable or tolerable intake of substances that exhibit threshold toxicity. The acceptable daily intake (ADI) or tolerable daily intake (TDI) or provisional tolerable weekly intakes (PTWI) are used to describe “safe” levels of intake for several toxicants including toxic metals (Andre *et al.*, 2005).

For most kinds of toxicity, it is believed that there is a dose below which no adverse effects will occur. For chemicals that give rise to such toxic effects, a TDI, i.e., an estimate of the amount of a substance in food expressed on a body weight basis (mg/kg^{-1} of body weight) that can be ingested over a lifetime without appreciable health risk, should be derived as follows:

$$\text{TDI} = \text{NOAEL or LOAEL} / \text{UF}$$

Where:

NOAEL = no-observed-adverse-effect level;

LOAEL = lowest-observed-adverse-effect level;

UF= uncertainty factor

The NOAEL is defined as the highest dose or concentration of a chemical in a single study founded by experiment or observation that causes no detectable health effect. Whenever possible, NOAEL is based on long-term studies, NOAEL obtained from short-term studies and studies using other sources of exposure (e.g., air) may also be used. If a NOAEL is not available,

a LOAEL may be used, which is the lowest observed dose or concentration of a substance at which there is a detectable adverse health effect, in this case, an additional uncertainty factor is normally applied.

The guideline value (GV) can be derived from the TDI, as follows;

$$GV = (TDI \times bw \times P) / C$$

Where: bw = body weight

P = fraction of the TDI allocated for that kind of food

C = daily consumption

Exposure exceeding the TDI value for short periods should not have a deleterious effect upon health. However, acute effects may occur if the TDI is substantially exceeding even for short periods of time. Additionally, contaminants possessing very long half-lives can be accumulated in the body and chronic effects are most often observed when critical concentrations are reached in target tissues. Once absorbed into the human body, inorganic toxic elements may induce several deleterious effects varying from irritating to acute or chronic effects. In addition to these toxic effects, some researchers describe another possible mode of action that is observed at low doses, named "hormesis ". Hormesis is defined as the stimulatory action of low dose (sub-inhibitory amounts) of a toxicant and it has been reported for a large number of chemicals including inorganics. (Andre, *et al.*, 2005).

Table 2. 1: Botanical names of the crops and their family

Common Name	Botanical Name	Family
Spinach	Amaranthus	Amaranthaceae
Cocoyam	Xanthosoma spp	Araceae
Sugar cane	Saccharum officinarum	Poaceae
Maize	Zea mays	Poaceae

2.6.1 Transfer factor (TF)

Soil to plant metal transfer was computed as transfer factor, (TF) which was calculated by using equation.

$$TF = C_{PLANT} / C_{SOIL}$$

Where C_{PLANT} is the concentration of heavy metals in plant

C_{SOIL} is the concentration of heavy metals in soil.

(Marisa and John 2007, Adeel and Riffat 2013).

2.6.2 Contamination/ pollution index

The contamination pollution index is defined by (Lacatusa, 2000) As c/p index = concentration of metal in soils/ Target value. The target value is a reference value of metals as obtained using the standard table formulated by the department of petroleum resources of Nigeria (DPR, 2002) for maximum allowable concentration of metals in the soil (Adaikpoh, 2013). The DPR target value of Cd 0.8 mg/kg, Cu 36 mg/kg, Pb 85 mg/kg and Zn 146 mg/kg. c/p index value less than 1 defined contamination ranges while value greater than one defined pollution as thus < 0.1 very slight contamination 0.10 - 0.25 slight contamination, 0.26 -0.50 moderate contamination, 0.51-

0.75 severe contamination, 0.76- 1.00 very severe contamination, 1.1- 2.0 slight pollution, 2.1 – 4.0 moderate pollution, 4.1 – 8.0 severe pollution 8.1 – 16.0 very severe pollution and > 16 excessive pollutions.

2.6.3 pH: Water dissociates by a very slight extent into H^+ and OH^- ions. It has been experimentally determined that in pure water $[H^+] = 1.0 \times 10^{-7}$ and $[OH^-] = 1.0 \times 10^{-7}$ and $[H] = [OH]$. The negative logarithms of 1.0×10^{-7} are 7.00; therefore, the pH of pure water is 7.00; such a solution is neutral and has no excess of either $[H^+]$ or $[OH^-]$. An excess of $[H^+]$ is indicated by a pH below 7.00 and the solution is said to be acidic. pH values above 7.00 indicate an excess of $[OH^-]$ or an alkaline condition. pH is the dissociation of water into H^+ and OH^- ions. It is a measure of acid-base equilibrium achieved by water dissolved compounds as well as the extent of flocculation and coagulation process of chemicals.

2.6.4 Electrical Conductivity

Conductivity is the numerical expression of the ability of an aqueous solution to carry an electric current. The ability depends on the presence of ions; their total concentration mobility increases with the temperature of the measurement system. Conductivity increases with temperature at a rate of approximately 19% deviation per degree Celsius. Significant errors can result from inaccurate temperature measurement. Solutions of most inorganic acid bases and salts are good conductors. Conversely, organic molecules that do not dissociate in an aqueous solution conduct the current very poorly (Maria, 1994).

2.6.5 Chemical Oxygen Demand

Chemical Oxygen Demand or COD is a measurement of the oxygen required to oxidize soluble and particulate organic matter in water.

Chemical Oxygen Demand is an important water quality parameter because similar to BOD; it provides an index to assess the effect discharged wastewater will have on the receiving environment. Higher COD levels mean a greater amount of oxidizable organic material in the sample, which will reduce dissolved oxygen (DO) levels. A reduction in DO can lead to anaerobic conditions, which is deleterious to higher aquatic life forms. The COD test is often used as an alternate to BOD due to shorter length of testing time (Real. Tech, Water, 2017).

2.6.6 Total suspended solid

TSS are solid materials, including organic and inorganic, that are suspended in the water. These would include silt, plankton and industrial wastes. High concentrations of suspended solids can lower water quality by absorbing light. Waters then become warmer and lessen the ability of the water to hold oxygen necessary for aquatic life. Because aquatic plants also receive less light, photosynthesis decreases and less oxygen is produced. The combination of warmer water, less light and less oxygen makes it impossible for some forms of life to exist. Suspended solids affect life in other ways. They can clog fish gills, reduce growth rates, decrease resistance to disease, and prevent the egg and larval development. Particles that settle out can smother fish eggs and those of aquatic insects, as well as suffocate newly hatched larvae. The material that settles also fills the spaces between rocks and makes these microhabitats unsuitable for various aquatic insects, such as fly nymphs, stonefly nymphs and classifies larva. Suspended solids can result from erosion from urban runoff and agricultural land, industrial wastes, bank erosion, bottom feeders (such as carp), algae growth or wastewater discharges. How can we prevent them from entering our surface waters? Prevention methods include protection of the land in our watershed from erosion by use of conservation tillage measures and giving urban runoff time to settle out before reaching our surface waters (Wikipedia.com 2017).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Research Design

The researcher used descriptive comparative analysis to establish the relationship between the level or extent of the dumping of these municipal waste and accumulation of these toxic elements in crops grown on the dumpsite field. Samples of crops, soil, and spring water were collected around the dumpsite field.

Geographical Scope

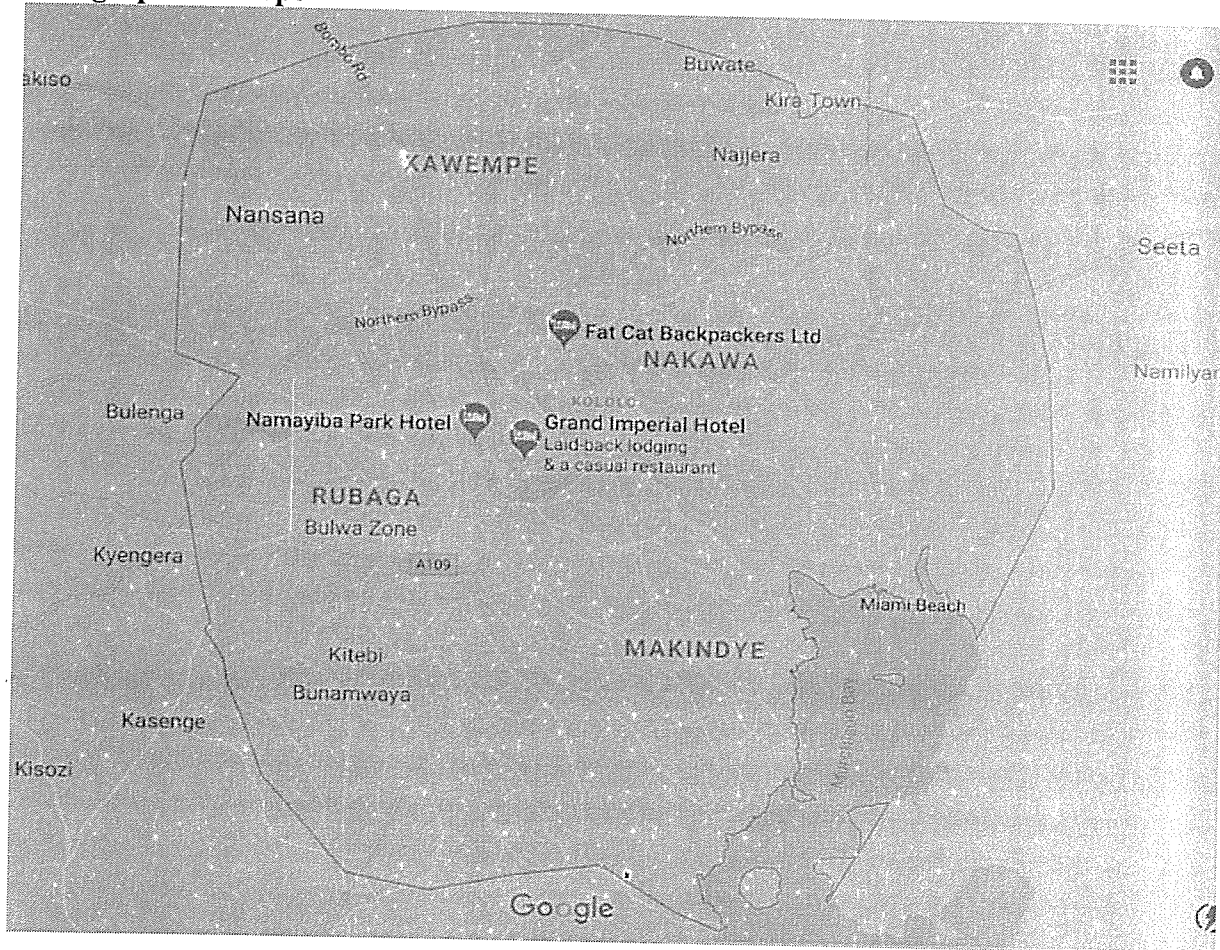


Figure 2: General Map of Kampala Showing Rubaga Division Where Wakaliga Is Located.

Sources; Google Map.

The study was conducted at Wakaliga an area within Kampala city, which is 9km from the city centre. Kampala has Coordinates: 00°18'49"N 32°34'52"E. Area total 189 km² (73 sq. mi), the land is 176 km² (68 sq. mi), water 13 km² (5 sq./mi). Elevation 1,190 m (3,900 ft). The population (2014 Census) Total 1,507,080 and density 7,928/km² (20,530/sq. mi).

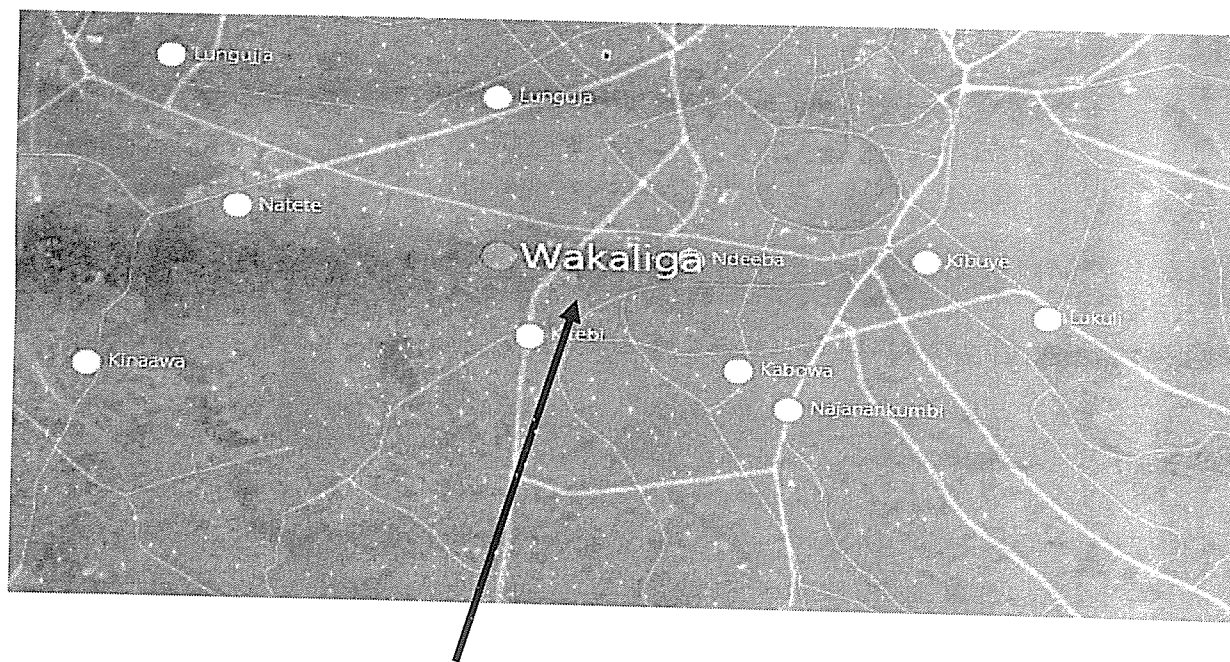


Figure 3: Map of Wakaliga the Arrow Showing the Study Area

Sources; Google Map.

3.1.1 Chemical Analysis

All chemicals were of analytical grade purchased from Merck and Fisher Scientific Ltd., UK.

3.1.2 Analytical procedure

Analyses of pH and temperature of water were carried out at the site of sample collection following the standard protocols and methods of American Public Health Organization (APHA,1992) and American Society for Testing and Materials (ASTM) using different calibrated standard instruments.

3.1.3 pH of the water samples

The pH of the water samples was measured by using a pH meter (Model HI 98130 HANNA). The pH meter was calibrated, with three standard solutions (pH 4.0, 7.0, and 10.0), before taking the measurements. Value of each sample was taken after submerging the pH probe in the water sample and holding for a couple of minutes to achieve a stabilized reading. After the measurement of each sample, the probe was rinsed with deionized water to avoid cross-contamination among different samples. (APHA,1992)

3.1.4 Conductivity

The conductivity of the samples was measured using a conductivity meter (Model DSS 307 SearchTech). The probe was calibrated using a standard 0.01M KCl solution. The probe was submerged in the water sample and the reading was recorded after the disappearance of stability indicator. After the measurement of each sample, the probe was rinsed with deionized water to avoid cross-contamination among different samples. Standard Analytical Methods for water A (1999).

3.1.5 Chemical oxygen demand (COD)

Chemical oxygen demand was determined by mixing 1.5ml of potassium dichromate with 3.5ml of concentrated sulphuric acid in a test-tube. The sample (2.5ml) was then added into the test tube and the solution was thoroughly mixed. The solutions were then put in an oven and digested for 2 hours at 150°C and allowed to cool to room temperature. The measurement was conducted using spectrophotometer at 600 nm wavelength. Adapted from (Mwegoha, and Kihampa 2010).

3.1.6 Total Suspended Solids (TSS)

The measurements of TSS in water samples were carried out according to the standard methods of APHA by filtration process. A 100ml volume of water sample was poured on a pre-weighed

glass filter of a specified pore size before starting the vacuum filtration process. The filter was removed after the completion of the filtration process and placed in an aluminium dish in an oven at 104°C for 2-3 hours to completely dry off the remaining water. The filter was then weighed, and the gain in filter weight represented the TSS contents, expressed in mass per volume of sample filtered (mg/L) (Standard Analytical Methods for Water Analysis, 1999). TSS is calculated using the expression:

$$mg/L = (A - B) \times 100 / mL$$

Where: A = weight of filter paper and residue; B = weight of filter paper.

3.2 Sampling in the wetland cultivation study sites

Sampling sites were located around Wakaliga dumping site, samples were collected in May and July 2017, and October -November 2017. Like any other town, and cities where population increased and waste management is still poor anything that loses value is sent to the dumping sites and others along the roads without sorting and separation. Small-scale factories like welding, car washing and garages have emerged and other activities that occupy the youth. These give out iron, copper, lead and cadmium particles which are left scattered all over the area. Secondly, this area for so long has been used as a waste dumping site with all sorts of wastes dumped there, be it organic, inorganic including even heavy metals which are brought as a result of runoffs from corroded iron sheets, oil spills from car washing sites and garages. When it rains all these find their way into the area. It is in here where agriculture is practiced because this area is believed to be fertile as a result of decomposition of these waste materials. Different Crop samples were taken at distance of 100 m apart, within the area experiencing intensive cultivation



of food crops by wetland encroachers. Three locations were selected, from which plant samples of various crops were freshly harvested.

3.2.1 Soil sampling

Soil samples were collected between May-July 2017, September October 2017 at Wakaliga farms, using hand auger and stainless-steel hand shovel at a depth of 25 cm to get a full presentation of each sample point. Since our crops have shallow roots such as spinach it was found reasonable to extend soil collection to a depth exceeding 50 cm to allow for leaching. The soil samples were picked from the exact point where plants were uprooted, packed in plastic bags and transported in a wet ice box to the laboratory (Maria, 1994).

3.2.2 Water sampling

Spring water samples were collected from 3 sources in and around the Wakaliga area farms using long narrow neck plastic bottle with Teflon cap, which was acidified with few drops of concentrated nitric acid to prevent contamination and transported to the laboratory for chemical analysis (Maria, 1994).

3.2.3 Plant sampling and chemical analysis

Samples of sugarcane, coco-yam corms maize and spinach (Spinach) were all collected from Wakaliga farms in Kampala suburb, using stainless steel knife, collected samples were Packed in polyethylene bags and transported to the laboratory. Three locations were considered for sample collection. The sugarcane stems were cut nearer to the roots, where the juice was expected to be more concentrated.

a. Sugarcane

The sugarcane stems were cut at two nodal intervals to the roots, washed, rinsed with deionized water, peeled and cut into small pieces with a stainless-steel knife and their mass determined. The specimens subsequently crushed with a stainless-steel blender. Then the juice was filtered by pressing it through a plastic sieve of 0.02mm. 50ml of the sugarcane juice extract was introduced into a 250 ml Pyrex conical flask and 20ml of dilute nitric acid added. The mixture was allowed to slowly evaporate on a hot plate just until precipitation occurred. A further 5ml of the nitric acid was added slowly until the solution turned clear and digestion complete. Thereafter 1 ml of 30% hydrogen peroxide was added to the flask, swirled and reheated for 10 min. When the solution remained clear upon cooling, 25ml of deionized water was added, and the solution boiled again. After further cooling, the contents were quantitatively transferred to a 25ml volumetric flask and made to volume. After settling for another 5 h, the contents were transferred to labelled plastic bottles.

b. Coco-yam

Cocoyam corms were thoroughly washed to remove all traces of soil and subsequently rinsed with deionized water. The specimens were prepared according to a standard procedure outlined by Okalebo and Gathua (1993).



Figure 4: Digestion of cocoyam corm samples

The coco-yam was peeled and cut into small pieces with a stainless-steel knife and dried to constant mass in an oven at 103°C for 24 h. After cooling, they were carefully ground in a ceramic mortar and passed through a 2 mm nylon sieve. The finely ground sample (1.250 g) was weighed in a clean dry 250 ml Pyrex conical flask. Concentrated nitric acid (25 ml; analytical grade) was added, followed by glass beads, and a funnel was put on the top of the flask. The contents were heated in a fume cupboard on an electric hot plate at medium heat until digestion was completed. A further 5 ml of the acid was added to the sample and the mixture concentrated to 10ml. Upon cooling, fresh 4 ml of 30% hydrogen peroxide was added, and the contents swirled and reheated for another 10 min. When the solution turned clear, the contents were cooled, and quantitatively 25 ml were transferred into a volumetric flask and made to volume with distilled deionized water. After settling for 5 h, the supernatant solution was carefully

transferred to plastic bottles, sealed with plastic covers and labeled and analyzed in the laboratory using AAS.

c. Green vegetables (Spinach)

The vegetables were cut into small pieces using a stainless-steel knife and dried in an oven at 103°C for 24 h to constant mass; due care was taken to avoid charring. After cooling, they were carefully ground in a ceramic mortar and passed through a 2 mm nylon sieve. The finely ground sample (1.250g) was weighed into a clean dry 250 ml Pyrex conical flask. Concentrated nitric acid (25 ml) added, followed by glass beads and a funnel put on top of the flask. The contents mixture was heated in a fume cupboard on an electric hot-plate at medium heat until digestion was complete. A further 5 ml of the acid were added and the mixture concentrated to 10mls.

On cooling, 4 ml of 30% hydrogen peroxide was added and the contents swirled and reheated for another 10min. When the solution turned clear, the contents were cooled and quantitatively transferred into a 250 ml volumetric flask and made up to the mark using de-ionized distilled water. After settling for 5 hr, the supernatant solution was carefully transferred to plastic bottles which were sealed with plastic covers and labeled and then subjected to spectrophotometric analysis for the PTEs using the AAS (Okalebo and Gathua 1993).

3.2.4 Soil sampling and chemical analysis

Soil samples were collected between May and July 2016, and September to November 2017, at Wakaliga dumpsite at a depth of 25cm using a hand auger. The soil samples were picked from the exact positions where plants were uprooted and packed in plastic bags and transported in an icebox at 0°C to the laboratory.

The hand auger was washed with deionised water, rinsed and dried before each use to minimize contamination. The soil samples were dried in an oven at 103°C for 24 hours, sieved using a 2 mm nylon sieve. The finely ground 1.25g of each sample was digested with nitric acid and hydrochloric acid (HCl / HNO₃ 3:1) in a 50ml Pyrex conical flask on an electric plate at medium heat. The digest samples were heated to near dryness and cooled. Then 5.0ml of nitric acid was added, followed by 4.0 ml of hydrogen peroxide and heated again to near dryness to complete digestion. The flask walls were washed with 10ml of de-ionized water and 25ml of hydrochloric acid was added to the mixture and heated again. The resulting supernatant was allowed to cool and transferred to 250 ml standard flask and made up to the mark with deionised water. Heavy metals such as copper, zinc, cadmium and lead were analysed by direct aspiration into Perkin Elmer Model 2380, flame atomic absorption spectrophotometer (AAS) (Okalebo and Gathua (1993)).

3.2.5 Water sampling and chemical analysis

Spring water was collected in a sampling plastic one-litre bottle, at an interval of 5 - 10m, in duplicate thrice around Wakaliga dumpsite spring, and pH, Temperature, and electric conductivity (EC) were measured and readings were recorded. The sample was then taken to the laboratory and analysed. At the time of analysis, 1 litre of the water samples from each site was evaporated to dryness. To the residue, the triple acid system [viz. concentrated nitric acid (10 ml), perchloric acid (2 ml) and hydrofluoric acid (4 ml)] was added. Then this solution was reheated to dryness. The final residue was reconstituted in 2 ml of 2 M hydrochloric acid, transferred to a 25 ml volumetric flask and made up to the mark with distilled water. The solution was then analysed using an atomic absorption spectrophotometer (Perkin-Elmer, Model 2380) using the Paul and Pillai method (Mbabazi 2010). This gave the total metal concentration in the samples and the result obtained is shown in Table 4.1

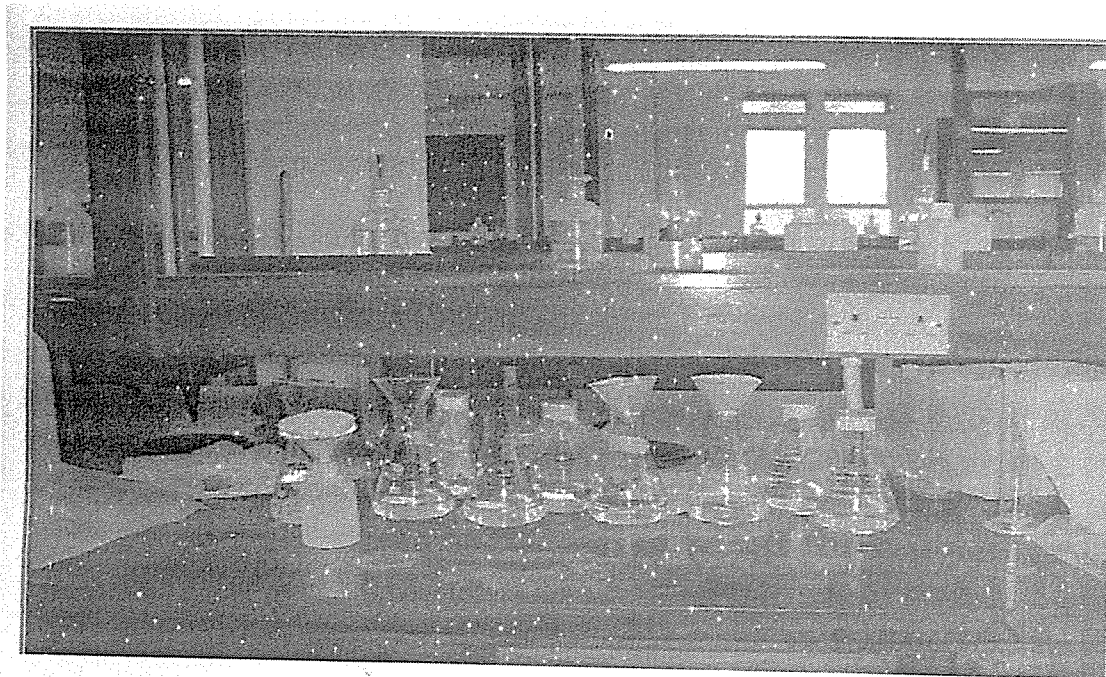


Figure 5: Packaging the clear supernatants in plastic bottles

3.2.6 Potentially toxic element chemical analysis

The clear supernatants resulting from the digestion procedures for crop samples were analysed for the heavy metals according to the standard procedure (Perkin and Elmer, 1996). Standard samples of heavy metals; lead, cadmium, zinc and copper were prepared from the stock solutions used to calibrate the atomic absorption spectrophotometer. The clear supernatants from the digestion of plant samples and experimental blanks were analysed for the potentially toxic element (PTEs); lead, zinc, copper and cadmium using a flame atomic absorption spectrophotometer under the standard operating conditions.

3.2.7 Instrumentation

In atomic absorption spectroscopy energy in the form of light excites the substrate to measurably higher levels.

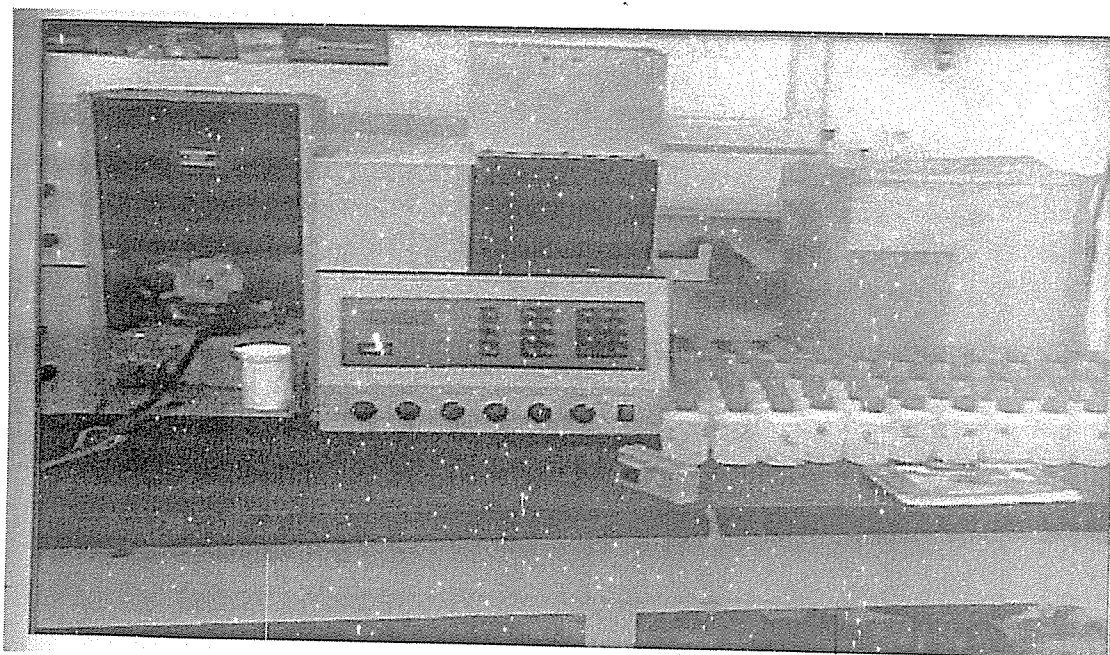


Figure 6: Samples before being analysed using the AAS.

Quantification is achieved through the use of Beer's Law that states

$$A = a * b * c$$

Where:

A= absorbance,

a = absorption coefficient,

b = path length and

c = the concentration of the substrate that is analysed.

Both a and b are constant for a given element and set instrument conditions. Therefore the equation may be simplified to

$$A = k * c.$$

Thus, a direct relationship exists between absorbance measured by the instrument and the amount of substrate responsible for that property.

Table 3. 1: Standard conditions for Atomic absorption spectrophotometer (AAS), for each element

Cd	
Wavelength	228.8 (nm)
Slit	0.7 (nm)
Relative Noise	1.0
Characteristic Concentration	0.028 (mg/L)
Linear Range	2.0 (mg/L)
Recommended Flame: Air-acetylene, oxidizing (lean, blue)	
Cu	
Wavelength	324.8(nm)
Slit	0.7 (nm)
Relative Noise	1.0
Characteristic Concentration	0.077 (mg/L)
Linear Range	5.0 (mg/L)
Recommended Flame: air-acetylene, oxidizing (lean, blue).	
Pb	
Wavelength	283.3(nm)
Slit	0.7(nm)
Relative Noise	0.43
Characteristic Concentration	0.45(mg/L)
Linear Range	20.0(mg/L)
Recommended Flame: air-acetylene, oxidizing (lean, blue).	
Zn	
Wavelength	213.9(nm)
Slit	0.7(nm)
Relative Noise	1.0
Characteristic Concentration	0.018(mg/L)
Linear Range	1.0(mg/L)
Recommended Flame: air-acetylene, oxidizing (lean, blue)	

3.2.8 Quality control

All glass wares and containers required for experimentations were first washed with distilled water followed by soaking in 10% nitric acid for few hours. This was done to ensure that no contamination occurred in them.

Further, analytical blanks were prepared by repeating the respective digestion procedures, minus the samples, and subsequently used to determine the instrument detection limits. In each case, a read-out from the screen was taken as the concentration of the selected metals.

3.2.9 Quality assurance

Three (3) samples were collected at Wakaliga dumpsite field namely soil, food crops, and spring water, between May- July, and September- October, randomize quadrates method was used to collect soil at a depth of 20-25cm, using hand auger. The soil was collected at the exact position where plants were uprooted, packed and labeled in plastic bags as S=n.

Where:

S = soil

N = 1, 2, 3, ... Okelabo and Gathua (1993).

Sugarcane was collected thrice (3) and cut at two nodal intervals to the roots, washed with deionized water. The samples were cut into small places and store in a labelled bag.

Coco-yam were collected thrice (3) washed with de-ionized water according to standard procedure (Okalebo and Gathn (1993).

Maize corn was collected thrice (3) stored in labelled plastic bag.

spinach leaves were collected whereby 30-40 leaves were collected for each vegetable sample, washed with deionized water to remove any dirt and soil. The polyethylene bags were labelled and then used to store the collected samples.

3.3 Statistical analysis

After data collection from the lab, Statistical techniques were used to calculate the mean and standard deviation that was used to determine accuracy and precision of the results.

3.3.1 Ethical consideration

All the samples collected in this research were based on the consent of the farmers who were contacted before any sampling activity in their farms was conducted. Some stipend money was given to farmers in some cases to get their permission.

All the related literature review used in this research are fully recognized by citing the relevant authors and academicians.

3.4 Limitations

Very few farmers cooperated with the researcher during sampling. This limited the researcher's ability to carry out more test on different food crops consumed by urban dwellers.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Physiochemical parameters.

All the physiochemical parameters are vital in environmental factors necessary for conductance of life process. pH is the dissociation of water into H^+ and OH^- ions, it is a measure of acid-base equilibrium achieved by water dissolved compounds as well as the extent of flocculation and coagulation process of the chemicals. Electric conductivity is the numerical expression of the ability of an aqueous solution to carry an electric current. The ability depends on the presences of the ions, their total concentration. Mobility increases with the temperature of the measurement system.

The domestic water (spring) quality was investigated in and around Wakaliga dump site because apart from being used for agricultural purposes. Quite a number of Wakaliga inhabitant depend on such water for domestic purposes. Clean drinking water is now recognized as a fundamental human right. Around 780 million people do not have access to clean and safe water around the world and around 2.4 billion people do not have proper sanitation. As a result, around 780 million people die each year due to water-related diseases (UN-Water,2013).

As result of these facts Wakaliga domestic water, was investigated to ensure cleanness and safety of the water for the public health protection. Physical parameters, such as pH, electric conductivity (EC), Chemical Oxygen Demand, (COD), total suspended solids (TSS) and some selected trace elements (Zn, Cu, Pb, and Cd) were investigated. The results for the findings are based on the two seasons dry season (May to July 2017), and wet season (September to November 2017) pH 6.96 ± 0.01 , wet season and 6.98 ± 0.01 dry season at $25^{\circ}C$ which respectively were found to be within the permissible limit for drinking water. E.C and TSS are below

permissible limits while COD has no guidelines, elemental zinc and copper are found to be below permissible limits; lead were all found to be above the permissible limits for both seasons. Cadmium, which is not detected in all the samples. The results obtained from dry seasons shows little variation from those obtained during wet season this is as a result of changes in high temperature, and ionic exchange which are found to be slow during the dry season. However, failure of the AAS machine to detect cadmium in both seasons doesn't mean that it is within. The recommended drinking water standard the recommended drinking water standard of 0.003 mg /l set by WHO (2011).

The most likely reason behind these lower obtainable physiochemical parameters of the domestic spring water is that spring water comes from the deep aquifers of the earth and travels through a network of cracks and fissure openings and pressure from deep aquifer, which may result in filtration and purification and results in loss of many elements and ionic compounds by reacting with them. The extent of dumping waste and other anthropogenic activities did not influence the purity and safety of Wakaliga spring water.

Table 4. 1: Physiochemical parameters and PTE concentration of spring water samples

Parameters	Units	Wet Seasons	Dry Seasons	US201/ WHO
PH		6.96±0.01	6.98±0.01	6.5-8.5
EC	µS/cm	230±0.77	150.4±0.27	1000uS/cm
COD	mg/L	97.7±0.73	40.1±0.14	No guidelines
TSS	mg/L	0.08±0.01	0.04±0.01	500
Zn	mg/L	0.46±0.01	0.11±0.00	5
Cu	mg/L	0.08±0.00	0.02±0.01	1-1.5
Pb	mg/L	0.04±0.01	* 0.02±0.00	0.01
Cd	mg/L	ND	ND	0.003

4.1.1 Zinc (Zn) levels in wet and dry season spinach (Spinach) soil

Transfer of metals from the solid to the solution phase of soils is thought to be influenced by several soil process which includes Cation exchange, specific absorption, precipitation and complexation (Riewerts *et al.*, 1998). Zinc in contaminated soils was reported by Adaikpoh, (2013) with a value of 78.82 mg/kg. Mahmood *et al.*, (2013) also found Zn on the contaminated soil to be within permissible limits. values of Zn which were found to be below the permissible limit on dump site soils by Opaluwa *et al.*, (2012) were 0.38 mg/kg, and 0.40 mg/kg. The mean concentration of wet season soil 1.07 ± 0.017 mg/kg dry weight Table 4.2 is lower than the dry

season soil with the value 3.70 ± 0.018 mg/kg dry weight; both seasons are all below the target limit of 50 mg/kg set by WHO (1996). These results are graphically represented in Figures 4.1 and 4.2. Dry season results are higher because absorption process, specific absorption involves the exchange of metal cations with surface ligands to form partially covalent bond with charge mineral surface (Alloway, 1995), also specific absorption is strongly pH depended, involves both organic and inorganic colloids (although mainly hydroxide) and often occurs when concentration of metal is low.

4.1.2 Zinc (Zn) levels in wet and dry season (cocoyam) soil.

Zn level in wetland soil was found to have concentrations 5.8 – 11.7mg/ kg dry weight which is below the permissible level. Mbabazi (2010), that soil concentration of heavy metal in urban and rural wetland cultivated soils. Highest mean concentration of Zn, in wet season soil, was found to be 3.70 ± 0.02 and the lowest 0.078 ± 0.01 mg/kg in maize crops Table 4.2 which is very low compared to 50 mg/kg set limit of WHO (1996) while dry season soil gives 2.83 ± 0.05 mg/kg d.w this indicates all the two-season result are below permissible limit, however dry season show higher level of Zn in the soil, then wet season soil. As can be represented in Figure 4.1 and 4.2 respectively This is as a result of higher cation exchange capacity in the dry season. The transfer factor during the wet season is found to be 10.8 above the standard limit of 0.48 – 5.07 table (8), a higher level of transfer factor indicates a higher metal concentration in the soil. During wet season due to urban runoff, that carries waste contains Zinc and compound from different sources while the transfer factor (TF) during the dry season is 1.62 relatively low.

4.1.3 Zinc levels in wet and dry season (sugarcane) soil.

Nabulo *et al.* 2008 report level of Zinc in wetland soils with the concentrations of 30.7 ± 3.2 mg/kg which is within the permissible limit of agricultural soil, and higher concentrations $387.5 \pm$

86.5, which is very higher concentration of Zn in the soil. In a research conducted by Twinomatsiko *et al.*, 2016, Zn levels of 151.36 ± 2.22 mg /kg. d.w. in the urban wetland soil. The highest mean concentration of wet season is 1.11 ± 0.07 mg/kg d.w. which is very low in comparison to 50 mg/kg WHO (1996) set limit for soils. Dry season highest mean concentration was 3.52 ± 0.020 mg/kg d.w Table 4.2 This show that the level of Zn is high in dry season compared to wet season soil. This may be attributed to cation exchange capacity, translocation and precipitation, and according to Bockhold *et al.*, 1995, the very high concentration of Zn can be absorbed before precipitation occurs. Figure 4.1 and 4.2 shows the variation between the absorbing elements in the soil graphically.

4.1.4 Zinc levels in wet and dry season (maize) soil

The metal Zn is an essential element needed by both plants and animals (Robert 2007) nevertheless, a high concentration of zinc can be toxic to the organisms. Ruqia *et al.* (2015) reported concentrations of zinc in soil samples ranged between 0.033 to 0.0349 mg/kg in all the soil concentrations was recorded below the permissible limit set by WHO. In this study at Wakaliga, area concentration in wet season soil was found to be 1.06 ± 0.09 mg/kg Table 4.2, which is lower compared to 50mg /kg set limit by WHO (1996). For the dry season, the mean concentration of Zinc was found to be 3.12 ± 0.018 mg/kg shown in Figure 4.1 and 4.2 below which is also below average WHO set limit.

4.1.5 Cu Levels in wet and dry season spinach (Dodoo) soil

Concentration range from 0.536 – 1.504 mg/kg was reported by Ruqia *et al.* (2015), also Nabulo *et al.* (2008), found that copper concentration in wetland soil ranges from lowest concentration of 19.33 ± 0.99 mg/kg which is lower when compared to the standard and highest value of 51.20 ± 8.69 mg/kg, these results are due to discharge of different chemical into the environment,

thereby polluting the soil. Concentration means of wet season soil was found to be 0.06 ± 0.00 mg/kg d.w Table 4.2, while 1.48 ± 0.01 mg/kg d.w for dry season soil sample was obtained all the samples show results that are remarkably lower than the world health organization WHO (1996) standards, of 36 mg/kg. Figure 4,1 and 4.2 shows a graphical representation of copper accumulates in the surface of the soil in the two seasons.

4.1.6 Cu levels in wet and dry season (cocoyam) Soil

Twinomatsiko *et al.*, (2016) found that urban wetland soils mean concentration of Copper was 18.22 ± 3.22 mg/kg d.w, and 36.23 ± 404 mg/kg d.w respectively, all were within the tolerable limit. The total mean concentration of copper in Wakaliga wet season soil was 0.04 ± 0.00 mg/kg d.w which was below tolerable WHO (1996) limit of 36 mg/kg Table 4.2, while the mean concentrations for the dry season were 0.95 ± 0.02 mg/kg, which was also low compared to the standard. This was attributed to the fact that heavy metals are mostly restricted to the topsoil about 15 cm³ since previous studies showed that surface soil is better indicators of metallic burden. This indicates that soils of wet season contain less Cu²⁺ metal due to leaching while dry season soil has high concentration due to cation exchange and binding capacity. Figure 4.1 and 4.2 shows the data results diagrammatically.

Table 1.2: Means concentration $\pm$ SD of wet and Dry season soils from Wakaliga Dumpsite

Seasons	Metals	Units	Spinach	Cocoyam	sugarcane	Maize	WHO
Wet Seasons	Zn	mg/kg	1.07 $\pm$ 0.01	0.09 $\pm$ 0.00	1.11 $\pm$ 0.07	1.06 $\pm$ 0.01	50
	Cu	mg/kg	0.06 $\pm$ 0.00	0.04 $\pm$ 0.00	0.04 $\pm$ 0.00	0.42 $\pm$ 0.01	36
	Pb	mg/kg	1.07 $\pm$ 0.01	0.09 $\pm$ 0.00	0.08 $\pm$ 0.00	1.06 $\pm$ 0.00	85
	Cd	mg/kg	0.01 $\pm$ 0.00	0.00 $\pm$ 0.00	0.01 $\pm$ 0.00	0.01 $\pm$ 0.00	0.8
Dry Seasons	Zn	mg/kg	3.70 $\pm$ 0.01	2.83 $\pm$ 0.03	3.52 $\pm$ 0.02	3.12 $\pm$ 0.001	50
	Cu	mg/kg	1.48 $\pm$ 0.01	0.95 $\pm$ 0.02	0.93 $\pm$ 0.03	0.78 $\pm$ 0.01	36
	Pb	mg/kg	2.58 $\pm$ 0.06	1.16 $\pm$ 0.02	0.96 $\pm$ 0.03	0.94 $\pm$ 0.02	85
	Cd	mg/kg	0.11 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.11 $\pm$ 0.00	0.8

Source: World Health Organization (1996). Adopted from (Ogundele *et al.*, 2015).

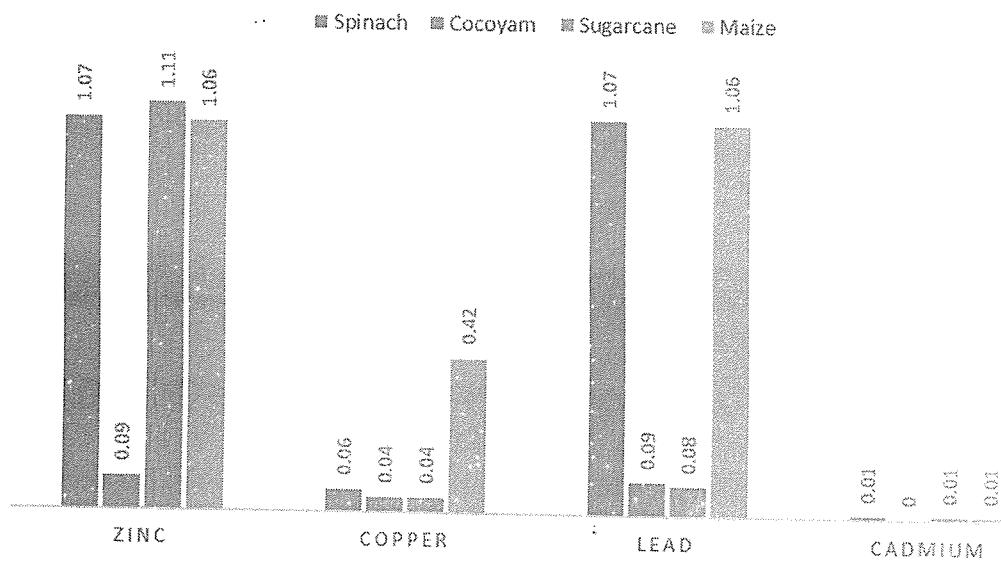


Figure 4. 1: Graph of mean concentrations wet season soils

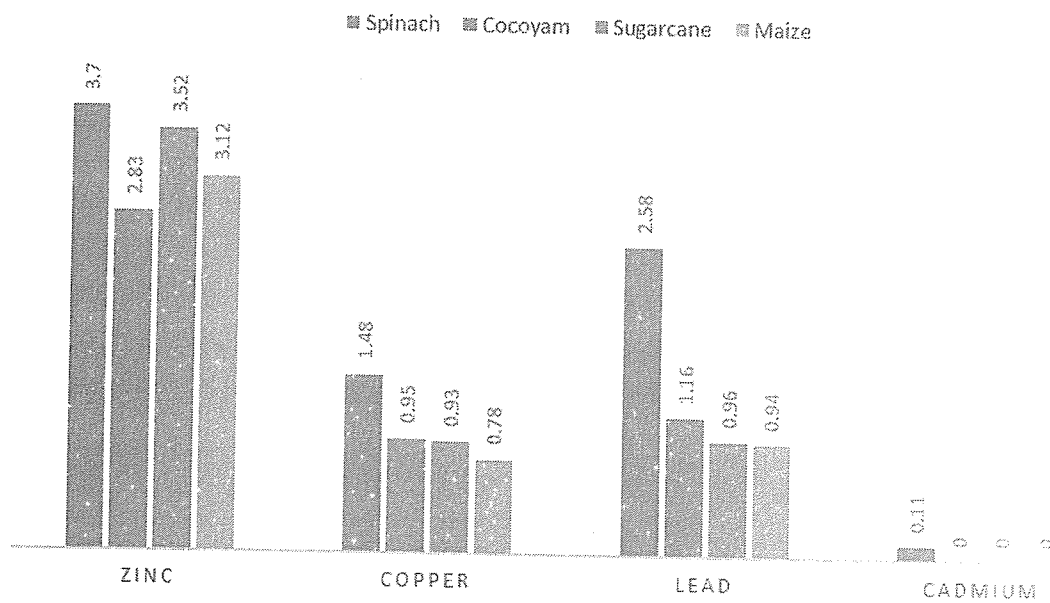


Figure 4. 1:Graph of means concentrations of dry season soils

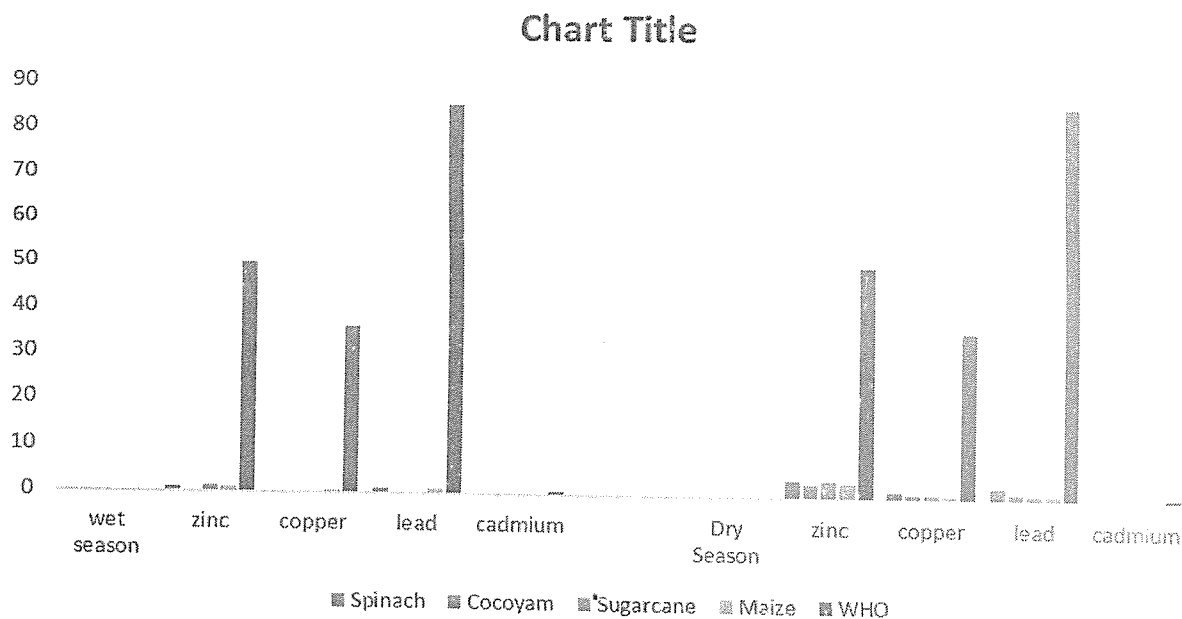


Figure 4. 2:Graph of means concentrations of wet and dry season soils with World Health Organization Standard

4.1.7 Copper levels in wet and dry season (sugarcane) soils

Copper, zinc and iron are essential for human nutrition but can be toxic if ingested in excess amount, narrow range of these essential metals is necessary to maintain health. Copper appears in electric wire pipes, in combination with other metals to form alloys as a mildew inhibitor and as a wood and leather preservative (Robert 2007).

Adaikpoh, (2013) reported Concentration average of copper 9.61 mg/kg 1.22 – 29.66 mg/kg 1.03 – 2.25 mg/kg, these concentration range is showing deficiency to minimum enrichment in the soil, accumulate in the surface horizon. Ogundele *et al.*, (2015) also found out that the concentration of copper in soil ranges from lower concentrations of 7.70 -60.33 mg/kg and concentration value of 28.55 – 1152 mg/kg all the sample ranges below detection limit while other were higher 80.13±0.0075. The mean concentration of copper in Wakaliga dump site wet

season soil was found to be 0.048 ± 0.00 mg/kg Table 4.1 which was very low compared to WHO (1996). Standard of 36 mg/kg, this was attributed to excessive leaching, while 0.93 ± 0.03 mg/kg d.w. was detected in dry season soil, which was a bit higher than the wet season the results are equally represented in Figure 4.1 and 4.2 show the variation between the two seasons, as a result of active binding capacity low-level teaching and accumulation of metal ions at a soil top surface.

4.1.8 Copper in wet and dry season (maize) soils

Mean concentration of Cu was reported by Nabulu *et al.*, (2008) ranges from 1.20 mg/kg lower concentrations, to 51.13 ± 1.72 mg/kg in wetland soils. Also, Opulawa *et al.* (2012) found lower concentrations of Copper in dumpsite soils ranges from 0.91, 0.82, and 0.34 mg/kg respectively all the values were below tolerable limit recommended by WHO and European Union (EU). In the Wakaliga study, the mean concentrations of Copper in wet season soil was found to be 0.42 ± 0.01 mg/kg Table 4.2, which was below permissible tolerated level set by WHO (1996) of 36 mg/kg while the total mean concentration of copper in dry season was 0.78 ± 0.01 mg/kg which was also lower but higher than the wet season this was attributed to pH change, temperature, and excess runoff which lead to excessive leaching of the available Cu^{2+} ions on the surface of soil.

4.1.9 Pb Levels in wet and dry season spinach (Spinach) soil

The concentration of lead in dumpsite soil was reported by Riziki (2010) ranges from 223.80 ± 146.73 mg/kg which is higher than the 200 mg/kg Contaminant level set for soil in Tanzania (TBS, 2007) concentrations 25.19 ± 13.99 mg/kg, 15.17 ± 1.20 mg/kg, 13.77 ± 2.96 mg/kg. Total wet season mean concentration of soil was 1.07 ± 0.01 mg/kg Table 4.2, which was very lower than WHO (1996) set limits for agricultural soil, while the dry season concentration was found to

be 2.58 ± 0.06 mg/kg the dry season concentration levels were higher than wet season due to temperature changes clay and soil texture. Figure 4.1 and 4.2 shows a representation of these differences graphically between the tested samples and the standard as well as variations between the two seasons.

4.1.10 Pb level in wet and dry season (cocoyam) soil

The mean concentration lead in wet season soil was found to be 0.09 ± 0.00 mg /kg, which was found to be low when compared to the standard 85 mg/kg, Table 4.2, dry season mean concentration of lead at Wakaliga was 1.16 ± 0.02 mg/kg dry weight, which was higher than the mean concentration in the wet season. The uptake of the metals by crops results in the bioaccumulation of these elements in plant tissue. This is known to be influenced by the metal species, plant species and plant part (Juste and Mench, 1992). Copper and Lead are strongly adsorbed on to soil particles reducing their availability to plant. WHO (1998).

4.1.11 Lead levels in wet and dry season (sugar cane) soil

The soil from the wet season showed a mean concentration of lead 0.08 ± 0.00 mg/kg Table 4.2 while the dry season soils showed the average concentration of 0.96 ± 0.03 mg/kg d.w. All the sample showed concentrations below the maximum contaminant level set by (WHO 1996). This may be attributed to the fact that many ionic compounds of metals are leach deeper into the soil horizon, beyond the reach of binders. Soil horizon also contributes to this variation in concentrations. Pb and Cu, are bound to organic matter as well as being adsorbed by carbonate mineral and hydrous iron and manganese oxides.

4.1.12 Lead levels in wet and dry season (maize) soil

The lead levels in soil or contaminated soil are reported by many researchers. (Mwegoha *et al.* 2010) reported lead in contaminated soils with concentrations of 22.85 ± 1.502 mg/kg as the highest concentration and 9.623 ± 1.086 mg/kg as the lowest concentrations of all the soils were within the maximum limit of 200mg /kg for soils. Wakaliga wet season soil mean of lead concentration 1.06 ± 0.00 mg/kg, while for dry season soil was found to be 0.94 ± 0.02 mg/kg d.w Table 4.2 But dry season lead concentration was lower than the wet season concentration but all the samples in both seasons were below tolerable limit set by WHO (1996) limit of 50 mg/kg. Figures 4.1 and 4.2 showed the result in both season and their differences graphically.

4.1.13 Cadmium level in wet and dry Season Spinach (Spinach) soil

Riziki 2010, reported very low Cadmium concentration from the dumpsite soils which was found to be very lower when compared to (TBS 2007). Also, Opoluwa *et al.*, 2012, reported Cadmium level at dumpsite soils, ranges from 0.32-0.48 from sample site to control site, all were below WHO and EU tolerable limits 0.2 mg/kg. Wakaliga wet season soil lead concentration was 0.01 ± 0.00 mg/kg d.w Table 4.2 and the dry season lead concentration was 0.11 ± 0.00 mg/kg d.w both seasons results were below the tolerable limit set by the US, (2017) WHO (1996). 0.003 mg/kg. Cd availability index (CDI) decreased with an increase in soil depth. (Qadir *et al.*, (2000). All the result variation between the two seasons were shown graphically in Figures 4.1 and 4.2.

4.1.14 Cd level on wet and dry season (cocoym) soil

The total mean concentration of cadmium in Wakaliga for both seasons was very negligible, wet season soil was extremely low of 0.00 ± 0.00 mg/kg and likewise the dry season soil concentrations were also recorded extremely low 0.00 ± 0.001 mg/kg Table 4.2 These values obtained for both seasons tested soils at Wakaliga dumpsite, was very lower compared to the standard levels of 0.8 mg/kg, or 0.2 mg/kg set by WHO, (1996).

4.1.15 Cd level on wet and dry season (sugarcane) soil

Adaikpoh, (2013) reported Cd concentration in soil samples ranges from 1.18 mg/kg to 2.3 mg/kg and found out they are within the natural Limits of 0.01 – 3.0 mg/kg in soil as set by European Council (1986) and Maff (1992) showing deficiency of Cd in most of the soil of the tested soils. In this Wakaliga study Cd concentration in dry seasons, soil was 0.11 ± 0.00 mg/kg d.w and wet seasons 0.01 ± 0.000 mg/kg Table 4.2 diagrammatically present in Figure 4.1 and 4.2 while the dry season concentration showed variation with bit higher concentration compared to the Cd concentration obtained in the wet season. This may be attributed to disposed of metals and compounds with cadmium coatings, materials, paints, and nickel-cadmium batteries that are found in the dumpsites around the study area. Also, motor vehicle tyres as the threads wear down cadmium released on the streets when it rains, cadmium washes into servers and end up in wetlands soils.

4.1.16 Cd Level in wet and dry season (maize) soil

All species of Cadmium are very toxic to humans and are non-essential. Cd is cumulative toxicant that affects kidney, bone metabolism and the reproductive tract and it is also carcinogenic and endocrine disruptor. Satarugu *et al.*, (2004). Also, Mbabazi *et al.* (2010) recorded Cd concentrations in wetland soils and with concentrations ranges from 0.68 ± 0.00 to 1.5 ± 0.00 which were within a tolerable limit. In this Wakaliga study wet season Cd mean concentration was 0.01 ± 0.00 mg/kg Table 4.2 while the concentration for the dry season was found to be 0.11 ± 0.00 mg/kg both are below mg/kg both are below the tolerable limit or 0.8 mg/kg WHO (1996).

4.1.17 Zinc level in wet and dry season spinach (Spinach)

Zinc is one of the important trace elements that play a vital role in the physiological and metabolic process of many organisms. However its higher levels can be toxic. Mean concentration of $145.37 \pm 10.21 \text{ mg/kg}$ were reported by Twinamatsiko *et al.*, (2016) in wetland spinach (dodo). The concentration of Wakaliga dumpsite cadmium in wet season spinach (Spinach) was found to be $1.96 \pm 0.03 \text{ mg/kg d.w}$ and $3.41 \pm 0.01 \text{ mg/kg d.w}$ for dry season Table 4.3 which are above permissible limit standard of 0.60 mg/kg set by WHO (1996). Table 4.5 showed the transfer factor which is the ability of the metal to bioaccumulation from soil to plant shows a considerable result variation between the two seasons 1.84 for wet seasons, while 0.92 in dry season, this according to (CSS, cornell.edu 2018), translocation of material within the soil profile is primarily due to gradient in water potential and chemical concentrations within the soil pores. Soluble minerals, colloidal material, organic compounds and iron may move up or down the profile between horizon with "water movement. The results obtained in Table 4.3 showed Zinc is above tolerable limits which may be attributed to the essential requirement nature of Zn element by the plant, which is needed by the plant for it grow but those of wet season. This factor may be attributed to higher mobility during the rainy season, PH, EC, soil texture. Wakaliga dumpsite, zinc viability or transfer factor of dry seasons was 0.92 Table 4.5 which is low compared to wet seasons 1.86, lack of much water which aid precipitation, and leaching may course decrease in transfer of zinc during the dry season from soil to the plants grow plant many retain the little concentration of zinc that is absorbed from the soil during the dry seasons. The data are presented in Figures 4.4 and 4.5 diagrammatically.

4.1.18 Zinc level in wet and dry season cocoyam

Amusan *et al.*, (2005) reported zinc concentration of urban dumpsite 15.93 ug/g cocoyam corm, and 9.34 ug/g cocoyam leaves, and transfer ratio of 0.40. The concentration of zinc in the wet

season, of Wakaliga dumpsite, were found to be 0.98 ± 0.02 mg/kg Table 4.3 Figures 4.4 and 4.5 which was found to be within limits set by WHO (1996) of 0.60 mg/kg while the highest dry season concentration of zinc was $2.7. \pm 0.08$ mg/kg, in Wakaliga dumpsite dry season results was above the permissible level set by WHO (1996) of 0.60 mg/kg. Amusan *et al.*, (2005), attributed the level of zinc concentration in urban dumpsite soils as a result of different living standards, consumption patterns and level of industrial development. In the cities and towns. In Wakaliga dumpsite the level of zinc was above-set limit may be attributed to many factors such as rapid active transport of metallic ions from soil to the plants. Ion exchange also amounts of zinc uptake. (Marisa and John 2006), relatively excess as a result of many sources of zinc in the environment.

4.1.19 Zinc levels in wet and dry season sugarcane

Twinamatsiko *et al.*, 2016 found high zinc concentration in sugarcane of wetland with ranges from 40.85 ± 4.36 mg/kg, 64.34 ± 11.34 mg/kg. In this study, wet season zinc concentration was 1.92 ± 0.08 mg/kg d.w. and dry season concentration was 3.31 ± 0.04 mg/kg d.w. Tables 4.3, while relatively high transfer factor of 1.73 was obtained in the wet season, and lower transfer factor obtained in dry season 0.94 Tables 4.5. Zinc concentration is above the permissible set limit by WHO (1996) of 0.60 mg/kg during the wet season most of the soil depths were wet and allow rapid active transport, and ion exchange and for transfer of heavy metal in ionic form, from soil to plant rapidly (Ukessay.com 2015). Zinc is essentially needed by plants as a trace metal requirement. This may attribute for retaining of significant concentration the plant, low level of transpiration in wet season also amount for high retention of zinc in the plans. Zinc is used in brake linings because of their heat conducting properties and as such released during chemical abrasion of the vehicle and from engine oil combustion and tires or motor vehicle.

(Hjortenkrans,2003). The concentration may also be as a result of decaying and decomposition of discarded materials in our dumpsite which consequently end up in our food crops.

4.1.20 Zinc level in wet and dry season maize.

Zinc from many sources ends up into our environment especially dumpsite whereby it can be corroded and degraded down into the earth surfaces which in turn absorbed by roots of our food crops as essential trace element requirement. Zinc concentration in wet season was found to be 1.04 ± 0.03 mg/kg Tables 4.3 in Wakaliga dumpsite which was above the permissible set limit by WHO (1996) 0.60 mg/kg. The transfer factor of 0.98 indicates higher transfer due to high diffusion and transpiration. Maize requires more trace elements including zinc for it to mature. In almost all the parameters determined in this study, dry season crops showed significant concentration or high value due to lack of high diffusion and increase in temperature and pH in soil. Zinc and copper were retained and stored in by the plant. Mean concentration of 2.35 ± 0.43 mg/kg was recorded during the dry season which was above the permissible set limit, but transfer factor 0.75. showed average mobility of the metal zinc in the maize corn.

4.2 Copper level in wet and dry season spinach (Spinach)

The permissible limit of copper for the plant is 10 mg/kg recommended by WHO (1996). In all the collected plant samples during the dry and wet season of Wakaliga were copper levels were below the permissible limit. Mean concentration of wet season was 0.07 ± 0.00 mg/kg and dry season mean concentration of 0.97 ± 0.00 mg/kg Table 4.3. The results from the transfer factor Table 4.5 showed wet season with the highest transfer factor of 1.25 when compared with dry season of 0.65, ions are more mobile when they are in solution.

Ruqia *et al.*, 2015 reports copper in different plant below permissible limits range from 0.79 ± 0.05 mg/kg 0.804 ± 0.040 mg/kg. and 0.66-0.744 mg/kg. Also, Opaluwa *et al.*, 2012 record

lowest copper levels from the dumpsite soils in Lafia metropolis 0.49 mg/kg. with the highest concentration, the soil from dumpsite give higher concentrations of 0.91 mg/kg and 0.82 mg/kg. Copper accumulates in liver and brain. Copper toxicity is a fundamental cause of Wilson's disease (Ruqia *et al.*, 2015).

4.2.1 Copper level in wet and dry season cocoyam.

Copper particles are released into the atmosphere by wind-blown dust, volcanic eruptions and anthropogenic sources primarily copper smelters and ore processing facilities. The concentration of copper in dumpsite farms have been reported by previous researches like Amusan *et al.*, 2005 who reported copper in different plant parts such as leaves, roots, cocoyam corm, and leaves ranges from 3.8521ug/g to 9.20ug/g. The maximum allowable level of copper by WHO (1996) is 10 mg/kg Table 4.5

Twinomatsiko *et al.*, 2016, reported the copper concentration of 6.01 ± 11.51 mg/kg from urban wetland within the tolerable limit and 12.32 ± 1.62 which are above tolerable limits. Copper mean concentration for wet season cocoyam corm from this study site was found to be 0.46 ± 0.02 mg/kg while the Concentration of dry season copper from the study site was found to be 0.06 ± 0.00 mg/kg Table .4.3, which was far below the maximum set limit of 10 mg/kg. The transfer factor was also considered for understanding the variation in concentration for both two seasons, very higher copper absorption 11.2. Transfer of the metal copper absorbed and very highest accumulation, but very few can be retained by the cocoyam plan which is needed is needed by the plants. However, during the dry season as plants absorb the metal very little concentration was retained by the plants as large concentration is loss through transpiration and precipitations. Transfer factor was 0.06 during the dry season.

4.2.2 Copper level in wet and dry season sugarcane.

Copper concentration from the study areas was found to be below the recommended set limit by WHO (1996) 10 mg/kg for both wet and dry season sugarcane. Wet season copper concentration was found to be 0.07 ± 0.00 mg/kg and dry season was 0.05 ± 0.00 mg/kg Table 4.3 Higher level of copper were reported by Twinomatsiko *et al.* 2016 in urban wetland 14.87 ± 16.21 mg/kg which was within the permissible set limit. The results obtained from this study area showed a higher level of copper was recorded during wet season this is as a result Cu level in plants are a function of various soil and climatic factors including PH, organic matter content, microbial activity and the soil moisture regime. Plants absorb copper as Cu^{2+} ion solution. Figures 4.4 and 4.5 indicated the season's variation of copper. The transfer factor between the soils and the plants for both season was showed in Table 4.5. Wet season showed high transfer factor of 0.13, whereas in dry season very low transfer factor of 0.68, very few metals was transferred from the soil to the plant.

4.2.3 Copper level in wet and dry season maize.

Copper is a trace element need for needed for human nutrition; the ATSDR estimates that in the year 2000 alone, approximately 1.4billion pound of copper were released into the environment during industrial processing. Robert (2007). Opaluwa *et al.*, (2012) reported that concentration of copper on a dumpsite in Lafia metropolis showed 0.48 mg/kg in maize a grain. In this study, wet and dry season concentration of copper in maize grains showed results which was below the tolerable set limit by WHO (1996) of 10 mg/kg. Mean concentration of wet season copper was 0.07 ± 0.00 mg/kg, while dry season copper concentration was 0.61 ± 0.01 mg/kg. The solubility of metal tends to increase at lower PH and decrease at higher PH values Rieuwert (1998). Absorption of metal is generally acknowledged to be directly proportional to the soil PH and this

has been observed for various absorbing soil components and different soil types. Transfer factor of 1.45 wet season, and 0.09 dry season Table 4.5.

4.2.4 Lead levels in wet and dry season spinach (Spinach)

Pb is known and used in ancient times; Pb is used in uncountable forms in the modern world from storage batteries, cable covering, plumbing ammunition manufacture of tetraethyl Pb Sound absorbers, radiation shields around x-ray equipment and nuclear reactors, paint lead pipes (PVC) paints among others. Researchers from around the world study its effect and presences both in soil, plant and water.

Mbabazi *et al.*, (2010) recorded high concentrations of lead in vegetables in urban wetlands ranges from 11.73 mg/kg-49.94 which were above the permissible limit. Ogundele *et al.* (2015) also reported the higher concentration of Pb in plants and in soil along heavy traffic roads in north central Nigeria from 24-397 mg/kg compared to the standard limit of 85 mg/kg. Concentration means of Pb of this study in wet season was found to be 1.03 ± 0.01 mg/kg while dry season concentration was found to be 2.34 ± 0.05 mg/kg Table 4.3 these concentrations were found to be within the permissible level by WHO (1996) of 2mg kg, which was within the acceptable limit. This variation between the two seasons may be attributed to many sources of lead and substances containing lead into the environment coursing soil pollution by surface runoff and atmospheric deposition of lead released by motor vehicle playing the road of Wakaliga area. Also, transfer factor showed a higher concentration of lead 0.95 in the dry season. during wet seasons 0.33 was found and remain in the plant and end up in our food chain.

4.2.5 Pb levels in wet and dry season cocoyam.

Cereals and vegetables are confirmed significant sources for the dietary intakes of these toxic elements. This contribute a higher percentage of daily intake of various elements through food

crops. Dietary intake of lead in cereals and legumes is 39.6 4.4, and 27.5 in vegetables. (Andre Luis *et al.*, 2005).

The uptake of metal ions has been shown to be influenced by the metal species and plant parts (Just and Mench, 1992). Musan *et al.* (2005) reported high concentrations of Pb in edible crops, grow on the municipal waste dumpsite with concentration ranges from 9.70-13.99ug/g and 17.0 mg/kg, in cocoyam corm leaves, pawpaw leaves and fruit. Okoraukwa *et al.* (2005) also record concentration of Pb which were very high 83.02 ± 27.84 mg/kg, 105.37 ± 45.37 mg/kg in leaves and roots of cocoyam grow on dumpsites. In this study mean concentration of Pb in wet season was 1.04 ± 0.01 mg/kg and 0.85 ± 0.01 mg/kg dry season was found in this study area. Compared to the fast researcher's findings, this study found out that Pb levels of wet and dry season cocoyam were all below limit of 2 mg/kg set by WHO (1996) and although the result obtained during wet season is higher than those of dry season, figure 9 and 10, this may be due to cocoyam as a tuber has not been exposed to the surface transpiration and evaporation that many leads to the loss of most absorb metals. Secondly, cocoyam contains large water content which helps to keep the metal ions in solution and remain in the crops for long period of time. One approach to assess the mobility of metal by plants is transfer factor (TF) the more mobile available the metal is (Morisa and John 2006).

4.2.6 Pb level in Wet and Dry Season Sugarcane

The entry of Pb into the food chain is a major concern, since it can cause chronic health problems. Plant can absorb Pb from soils and from a Pb exhaust from traffic-induced contaminated atmosphere this source was responsible for more than 90% of total Pb emissions into the atmosphere in congested urban areas. Leaded gasoline fuel and traffic volume were

strongly correlated with the concentration of Pb in various environmental media. Atmospheric and soil Pb can contaminate water and consequently enter the food chains (Kaste *et al.*, 2003). Ruqia *et al.*, (2015) recorded lead at very low concentrations in some leaves of plants while in the roots of some plants, the level was found to above permissible limits. Twinomatsiko *et al.* (2016) also reported the concentration of Pb in sugarcane grown on urban wetland soil with a concentration of 14.87 mg/kg. He attributes the higher concentration of urban wetland to plant absorb Pb form directly through the leaves, by the leaded gasoline vehicles releasing the lead which plant absorb directly especially in urban sites. The concentration of Pb in wet season Wakaliga dumpsite was 0.01 ± 0.00 mg/kg and 0.74 ± 0.07 mg/kg dry season (Table 4.3). From the extract of sugarcane, the concentration of both seasons is within the limit set by WHO (1996) of 2 mg/kg. This was as a result of very low transpiration in sugarcane as sugarcane lacks much leaves that can enhance more transpiration. Pb and other toxic element uptake increases in plants that are grown in areas with increased soil contamination Figures 4.4 and 4.5 represent the variation between two seasons graphically (Marisa and John 2006).

4.2.7 Pb level in maize corn in dry and wet season

According to Andre *et al.*, (2005) Pb may be ingested by eating or drinking contaminated food and also by swallowing large particles (diameter greater than 5 μ m). Cosmetics including lip balm is also an important source of Pb contamination (Pirkle *et al.*, 1998) Miller *et al.* (2004). Pb is a zootoxic metal and most people and animal receive the largest portion of their daily Pb intake in food. The most important pathway whereby atmospheric Pb enters the food chain is through to be direct folia contamination of plant. previous research on dumpsite reported Pb concentrations in maize. Okoronwo *et al.* (2005), also recorded the mean concentration of Pb in contaminated dump site soils ranges from 111.75 ± 17.78 mg/kg to 16.63 ± 19.94 mg/kg, respectively, in roots and leaves cassava.

Mean concentration of lead in wet season maize corn was 0.02 ± 0.00 mg/kg while 0.71 ± 0.02 mg/kg was recorded during the dry season (Table 4.3) both the two-season concentration are found to be within permissible set limit by (WHO 1996) of 2 mg/kg. although the dry season result is higher than the wet season as a result of high diffusion during the dry season and high transpiration, and pH increase, increase the availability of the ion absorption. During raining season there is low pH which in turn decrease the absorption of cations. The transfer factor (TF) for the dry season is also high at 0.75 compared to wet season 0.02.

4.2.8 Cd levels in Spinach (Spinach) in dry and wet season

Cd is a non-essential element and all of its compounds are considered to be highly toxic to humans. Food contamination is the most important pathway of Cd exposure to the general population, excluding smokers. Cd is more readily take up by plants than other materials such as lead. The concentration of Cd in foods is related to its level in the soils and its bioavailability, crops cultivated in the contaminated soil will present High concentrations of Cd than those from uncontaminated ones. Plant-based foods grown in uncontaminated soils rarely exceed 0.2 mg/kg of Cd calculated on a fresh weight basis. Some roots crops (carrots and parsnip) and some leafy crops (lettuce and spinach) are able to accumulate more Cd than other plant foods. Other foods such as rice and wheat can accumulate relatively high amounts of Cd when grown in contaminated soils. According to world health organization the standard limit for Cd in food crops is 0.02 mg/kg. The mean concentration of Cd in wet and dry season of this study was 0.00 ± 0.00 mg/kg and 0.01 ± 0.00 mg/kg respectively (Table 4.3) the results are all below the set limit of WHO (1996) of 0.02.

4.2.9 Cadmium levels in dry and wet seasons cocoyam

Previous researches have proved the presences of cadmium in plants grown on dumpsite contaminated soil, Opaluwa *et al.* (2012) reported concentrations of cadmium in dumpsite soil

0.03 mg/kg to 0.84 mg /kg. In his work at urban wetland soils Twinamatsiko *et al.* (2016) reported the higher concentration of cadmium 1.35 ± 0.44 mg/kg to 0.25 ± 0.02 mg/kg, which was higher than the set limit. Okoronkwo *et al.* (2005), similarly reported cadmium concentrations of 4.10 mg/kg both roots and leaves of cocoyam. The daily intake of Cd was estimated at 25-60ug for a 70kg person from uncontaminated areas, but the value of 10 to 61ug day⁻¹ have also been reported (Andre *et al.* 2005). The Cd concentration for both wet and dry season of this study was 0.00 ± 0.00 mg/kg and 0.00 ± 0.00 mg/kg dry seasons. Cd levels in wet and dry season were below the set limit by WHO (1996) of 0.02 mg/kg, and there is more moisture underground and low temperature which favour high diffusion while during dry season there is less moisture and so diffusion is less but retention of the ionic element is high by the tuber. Also, cation exchange capacity during the dry season is higher.

4.2.10 Cd level in sugarcane in wet and dry seasons

Cadmium adversely affects several important enzymes, it can also cause painful osteomalacia (bone disease) destruction of red blood cell and Kidney damage. Cadmium is chemically very similar to zinc and is found in the +2-oxidation state. It is believed that much of the psychological action of cadmium arises from its chemical similarity to zinc specifically Cd may replace Zn in some enzymes thereby altering the stereochemistry of the enzyme and impairing its catalytic activity (Okoronkwo *et al.* 2005).

Concentration of 0.74 ± 0.31 mg/kg and 0.13 ± 0.07 mg/kg were recorded in wetlands sugarcane by Twinamatsiko et al (2016). The maximum contaminant level of Cd concentration in plants set by WHO, (1996) is 0.02 /kg. In this research the wet and dry season, sugarcane indicate the very negligible mean concentration of 0.00 ± 0.00 mg/kg and 0.00 ± 0.00 mg/kg was obtained

4.2.11 Cd levels in wet and dry season maize

Table 4.3 showed very negligible concentration of Cd in both wet and dry season maize 0.00 ± 0.001 mg/kg and 0.00 ± 0.00 mg/kg. The result obtained was found to be all below permissible WHO set a limit of 0.02 mg/kg similar results obtained by Opoluwa et al, (2012) in maize crops grown dump site soils, were within limits 0.11 to 0.26 mg/kg.

Table 4. 2: PTE concentration (mg/kg) in Wet and Dry season crops

Seasons	Metals	Units	Spinach	Cocoyam	sugarcane	Maize	WHO
Wet Seasons	Zn	mg/kg	1.96 ± 0.01	0.98 ± 0.02	1.92 ± 0.08	1.04 ± 0.03	50
	Cu	mg/kg	0.07 ± 0.00	0.46 ± 0.02	0.07 ± 0.00	0.07 ± 0.00	36
	Pb	mg/kg	1.03 ± 0.00	1.04 ± 0.01	0.01 ± 0.00	0.02 ± 0.00	85
	Cd	mg/kg	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.8
Dry Seasons	Zn	mg/kg	3.41 ± 0.01	2.7 ± 0.08	3.31 ± 0.04	2.5 ± 0.4	50
	Cu	mg/kg	0.97 ± 0.00	0.46 ± 0.01	0.05 ± 0.00	0.71 ± 0.01	36
	Pb	mg/kg	2.31 ± 0.05	0.85 ± 0.01	0.74 ± 0.01	0.71 ± 0.02	85
	Cd	mg/kg	0.01 ± 0.00	0.01 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.8

Source: World Health Organization (1996). Adopted from Ogundele DT *et al.*, 2015.

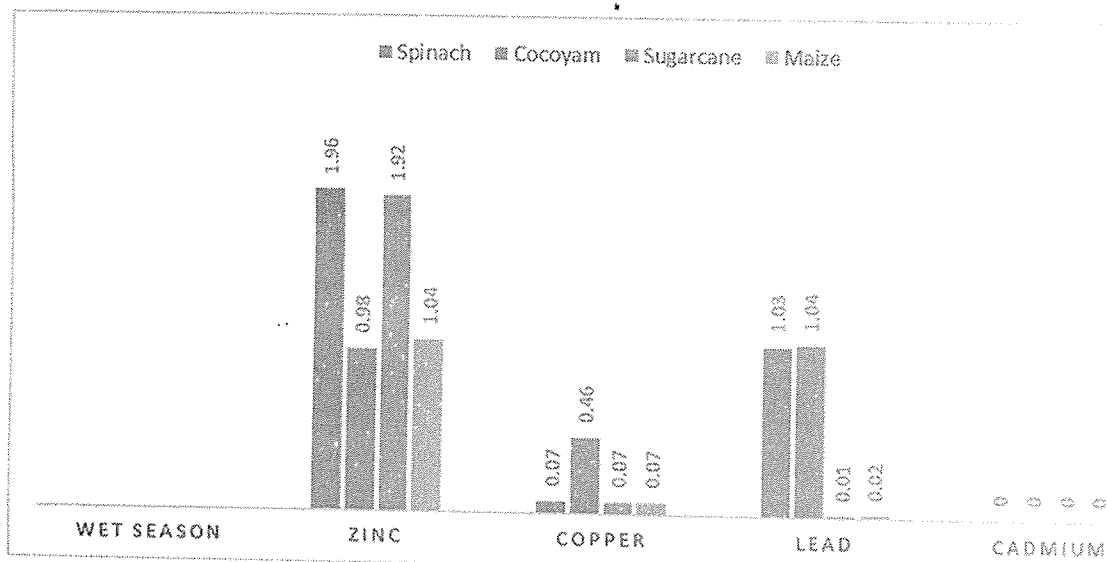


Figure 4. 3: PTEs concentration (mg/kg) in Wet Season Crops

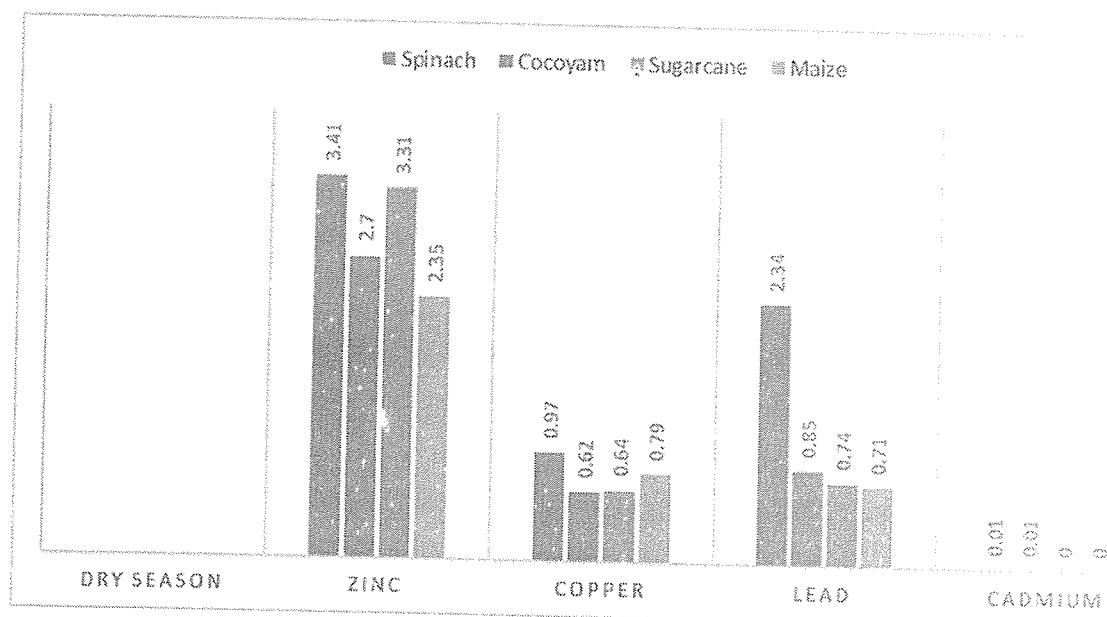


Figure 4. 4: PTEs concentration (mg/kg) in Dry season crops

Table 4. 3:Transfer factor Ratio

Wet Season Dry Season

	Zn	Cu	Pb	Cd	Zn	Cu	Pb	Cd
Plants								
Spinach	1.84	1.25	0.96	0.28	0.92	0.65	0.90	0.07
Cocoyam	10.8	11.2	10.9	0.5	1.62	0.06	0.74	0.85
sugarcane	1.73	0.13	0.22	0.07	0.94	0.68	0.77	0.8
Maize	0.57	1.45	0.02	0.26	0.75	0.09	0.75	0.04

4.2.12 General Discussion

The study was conducted to identify and compare the levels of the selected potentially toxic element (PTEs) in contaminated soils, water and some food crops from Wakaliga dump site in Kampala. Two seasons were used for sampling.(wet and dry season). After all the samples were digested and analysed, the results obtained show that PTEs were a bit higher in dry season crops when compared to the wet season. This was attributed to many factors such as pH, Conductivity, Temperature, dilution and diffusion, soil physical property, such as moisture content and organic matter (Rieuwerts *et al.* 1998). Others according to Marques *et al.*, (2009) includes, density and type of charge in soil colloids, the degree of complexation with ligands, and the soil relative surface area. Table 4.2 shows the result of the concentration of PTEs in the soil. While Table 4.3 shows results obtained for both seasons for all the crops Table 4.1 shows physiochemical parameters as well as some of the PTEs and trace metal results in domestic (spring) water. Some of the results obtained were within the tolerable limit set by WHO/FAO, EPA, US, NEMA,

while others were below the permissible limits. From the findings of this research, an element such as Zinc was found to be higher in all the crops and soils. Zinc is an essential trace element, necessary for plant, animals and microorganisms (Prasad, 2008, Broadley *et al.*, 2007), Zinc Serves as structural ions in transcription factors and is stored and transferred in metallothioneins. It is "typically the second most abundant transition metal in organisms" after iron and it is the only metal which appears in all enzyme classes (Broadley *et al.*, 2007).

In proteins, Zn ions are often coordinated to the amino acid side chains of aspartic acid, glutamic acid, cysteine and histidine. The theoretical and computational description of this zinc binding in proteins (as well as that of other transition metals) is difficult (Brandt *et al.*, 2009). The relative high level of Zn in the sample for both season may be attributed to iron and steel production, fuel combustion, fertilizer and pesticides, atmospheric fallout, Zinc containing waste from agricultural and animal wastes manure, and sludge, corroded galvanized roofing sheets, old water pipes, cosmetics and pharmaceuticals all found in discarded waste. The lead was found to be second most absorbed metal after zinc. This is due to the fact that lead-containing substances are found everywhere in the environment from gasoline, water pipes, paints, building materials, glass batteries etc. apart from absorbing lead metals from the ground through the roots by translocation, plants may possibly get their lead concentration directly through the leaves from the atmospheric lead pollution released by vehicles moving along Wakaliga area. Copper was found in small quantity in all the crops and the soil sample as well as water samples, copper is one of the transition elements needed by plants and animals, and for human health. A human adult contains around 100mg of copper, mostly attached to a protein, an amount exceeded only by iron and zinc and required daily intake of 3-5mg. Copper deficiency results in anaemia and congenital inability to excrete Copper results in its accumulation is Wilson's disease (Greenwood

et al., 1986). Lower concentrations obtained may be as a result of that Cu and Pb being strongly absorbed into soil particles reducing their availability to plants (WHO, 1998). Cation Exchange Capacity is apparently reduced due to the humans occupying the dumpsite, building houses and other socio-economic structures which drastically reduce the number of metal intakes by the plants. Heavy rainfall contributes to the leaching of the available metals on the topsoils.

Cation exchange capacity; most nutrients are cations such as Ca^+ , K^+ , NH_4^+ Zn^{2+} , etc. These cations are in the soil solution and are in dynamic equilibrium with anions adsorbed on the cations which are also adsorbed on the surface of clay and organic matter. Cation Exchange Capacity is a measure of the quantity of cation that can be adsorbed and held by a soil. Cation Exchange Capacity is dependent upon the amount of organic matter and clay in soil and on the types of clay, in general, the higher the organic matter, and clay content the higher the cation exchange capacity (Tree Research and Extension 2004). The ability of plants to accumulate essential metals enable them to acquire other non-essential metals. (Djingoba and Kuleff, 2000).

Table 4.5 shows the relationship between the movement (mobility) of these elements from their original sources (soil) to absorption sources (plants) known as Transfer Factor. Heavy metal accumulation in plants depends upon plant species. The efficiency of different plants in absorbing metals is evaluated by either plant uptake or soil to plant transfer factors of the metals (Karanja *et al.*, 2010). Generally, metal uptake is increased in plants that are grown in areas with increased soil contamination. Among the metals, Cd and Zn are fairly mobile and are readily absorbed by plants (Mench *et al.*, 1994). This also may contribute to the higher presence of Zn metal in Wakaliga dumpsite. The higher the value of transfer factor, the more mobility available the metal. Metals are specifically absorbed in the preferential order $\text{Cd} < \text{Zn} < \text{Pb} < \text{Cu}$ (Rieuwerts *et al.*, 1998).

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

All the soil samples collected were found to be below permissible set limits by WHO/FAO, for agricultural soils, but for plants and water, there were variations between the two seasons most dry seasons samples (plants, water and soil) showed a significant increase when compared to those from wet season. But may not rule out the fact that with time these metals uptake by the plants may be increased due to many environmental factors especially increase in the level of toxic containing waste, indiscriminate disposal surface runoff and pH. Which may subsequently bioaccumulation and end up causing serious health hazards to the consumers of these food crops. In all the collected samples, zinc showed significant absorption, especially during dry season. This is as a result in changes in temperature, increased in binding capacity by the soil due to or absence of rain and the increased in pH. Zinc concentration as seen by the results is not surprising because zinc is an essential trace metal required by the plants themselves for their growth. Lead is second most absorbed element though lead is toxic and can potentially cause several dangerous diseases. Plants absorb more of lead because there are several substances containing lead that are available in our waste, from household, industries, which directly release them to the dumping site or to the atmosphere. As Wakaliga is located in an urban centre motor – vehicles contribute massively in contaminating atmosphere with lead from leaded fuels, which is in turn absorbed by plants through their leaf follicles. Bioavailability of PTEs in the soil depends to a large extent on their distribution between the solid phase and the solution phase. This distribution is, in turn, depend on the soil processing, cation exchange and specific adsorption. pH is generally acknowledged to be the most important influencing factor on metal bioavailability in solution, with solubility and pH showing an inverse relationship. Lower

concentrations obtained for Pb, Cu, and Cd in this study may also be due to the fact that of this study area has long been used as a dumpsite location, people for long time have now occupied the area settled built houses and other social-economic structures, subsequently reducing the size of the waste disposal area furthermore high rainfall of Kampala city may also be a contributing factor to high-level leaching of the available PTEs from the topsoil surfaces, known as O-Horizon and A- Horizon in the soil profile. The elements are out of reach of most studied crops roots that cannot exceed A- Horizon.

Trace elements in the domestic spring water are also within the tolerable limits and are not causing health hazards, and most of the anthropogenic activities around Wakaliga and beyond did not much influence the quality of the spring water.

5.1 Recommendations

1. People should be enlightened on how to sort and separate their waste before disposing of them, by introducing reuse, reduce, and recycle methods of waste disposal for domestic waste. Industries should introduce pre-treatment methods before finally disposing of their waste as this will reduce the level of toxic elements going into the environment.
2. Proper waste management, control, disposal, design and control should be handled by a reputable private, government and non-governmental organizations to ensure dangerous and toxic substances do not end up in our environment.
3. Modern urban farming with low-cost should be introduced to these local farmers that practice this urban agriculture on dumpsite or old vacant spaces. For instance, vertical farming, which is more economical and less toxic since the water and the soil used in this farming are checked regularly.

4. All the spring water collection points should be provided with modern water pitting in order to minimize water contamination from the collection points. Those collection points are too unhygienic.
5. Health and environmental authorities should be checking the physical and chemical state of the water on regular bases, like any other domestic water supply because large numbers of people depend on such water for their daily need.
6. The study results should be used as a baseline for further study of all the water bodies, dumpsites and other environmental samples so as to get a better understanding of the magnitude of heavy metal contamination in Kampala city.

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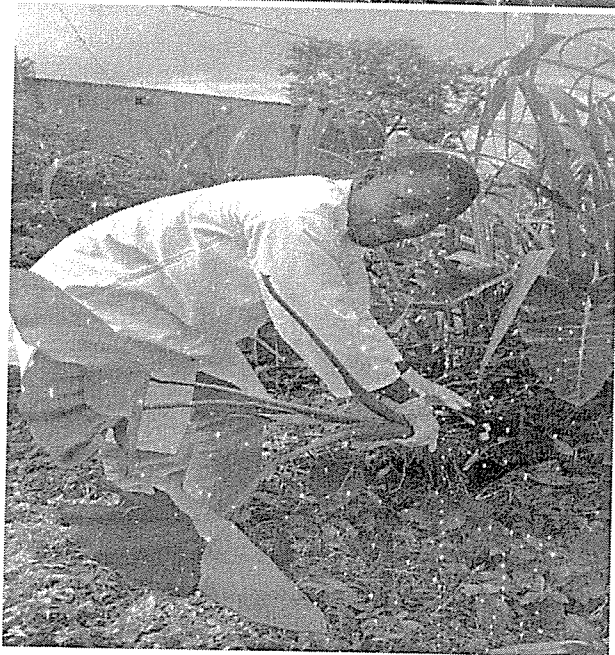
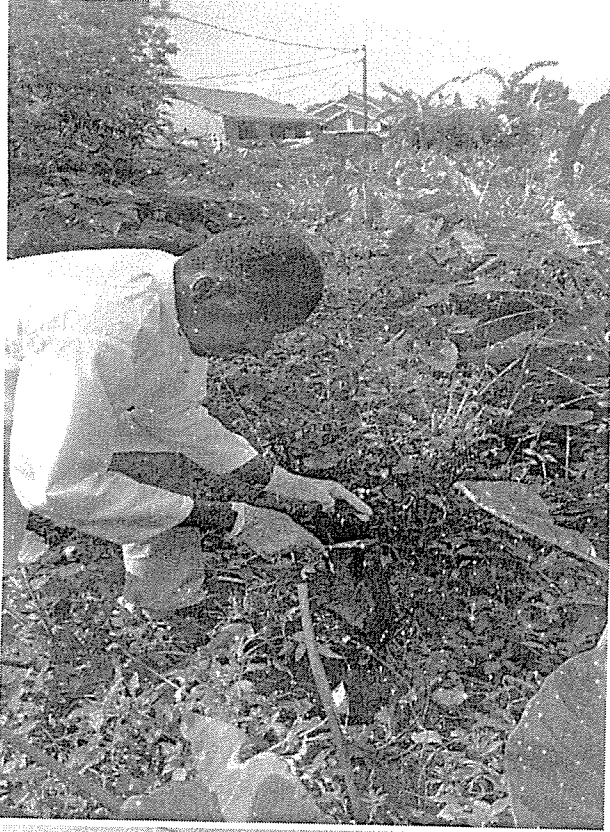
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APPENDICES:

Appendix I: Soil, Crops, and Water Sampling Collection





APPENDIX II

Appendix II: Maximum Contaminant Levels of Element in Soil/ Target Value Of Soil.

ELEMENT	MCL(SOIL) Targeted value of soil mg/kg	MCL IN PLANT mg/L
Zn	50	0.60
Cu	36	10
Pb	85	2
Cd	0.8	0.02

Source: Denneman and Robberse 1990; Ministry of Housing, Netherlands 1994.

Source : world Health Organization (1996). Adopted from Ogundele D.T. *et al.*, 2015.

APPENDIX III

Appendix III: Maximum Contaminant Levels for Drinking Water

Parameters	MCL
pH	6.5-8.5
E.C	1000-4000us/cm
COD	No guidelines
TSS	500

SOURCES: EPA 2003, NIS 2007, WHO 2005.

APPENDIX IV

Appendix IV: Transfer Ratio (TF) Standard

Metals	Ranges
Zn	0.48-5.07
Cu	0.01-2.17
Pb	0.0-0.9
Cd	0.0-2.7

(Marisa and John 2006).

APPENDIX V

Appendix V: Fao/Who Guideline for Metals in Food Crops and Vegetables

Metal	WHO/FAO	NAFDAC	EC/CODEX	NORMAL RANGE IN PLANT
Zn	60	50	<50	20-100
Cu	30	20	0.3	2.5
Pb	2	2	0.3	0.50-30
Cd	1	-	0.2	<2.5

SOURCES; Opaluwa, O. D et al 2012.

APPENDIX VI

Appendix VI: Transmittal Letter



Ggaba Road, Kampala, Uganda.
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SCHOOL OF ENGINEERING AND APPLIED SCIENCES
DEPARTMENT OF PHYSICAL SCIENCES

TO WHOM IT MAY CONCERN

31st October, 2017

RE : MR. NURA TASIU

I am writing in support of Mr. Nura Tasiu's request to collect data for his research on potentially toxic elements in food crops grown on urban dumpsite, Wakaiiga, Kampala.

Mr. Nura Tasiu with Registration Number **1161-03306-04494** is pursuing his master's degree in Chemistry which is a two year program at Kampala International University in the department of Physical Sciences.

We appreciate the service rendered to him.

Yours Sincerely,

MARIA MBATUDDE (PhD)

Head of Department, Physical Sciences

