HEALTH RISK AND HEAVY METALS ASSESSMENT IN SOILS AND VEGETABLES AROUND SECOND CEMETERY, IYAKPEN, BENIN CITY.

BY

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A PROJECT SUBMITTED TO

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CERTIFICATION

This is to certify that this work was carried out by Udogwu, Nnadiobumma Gloria, Mat. No. ENG1804906, of the Department of Civil Engineering, Faculty of Engineering, University of Benin City, Edo State, Nigeria

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DEDICATION

This work is dedicated to God Almighty for his grace, strength, wisdom, knowledge, understanding and provision all through the period of this project execution, and also to my mom, late Mrs Nkechi Doris Udogwu, for her faith and belief in me.

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ABSTRACT

In this study, the levels of tin (Sn), antimony (Sb), iron (Fe), cadmium (Cd), lead (Pb), and zinc (Zn) in soil and vegetables were examined, as well as the potential health risks of eating vegetables obtained from areas around second cemetery, Iyakpen, Benin City, Edo state, Nigeria.

Soil samples were collected with hand auger from 0 – 20cm depth, air-dried, powdered, and sieved. Four different vegetables (mango, orange, potato and bitter-leaf) were also were randomly collected from around the cemetery and transported to University of Benin Civil engineering laboratory, Benin City, Nigeria, for sample preparation. The vegetables were washed with distilled water to remove any traces of dirt, separated, air-dried and further dried in oven for 72 h at 65 °C to attain constant weight. The dried leaves were then pounded with a mortar and pestle and converted to powder and stored each in a plastic bag for analysis. The soil and vegetable samples were analyzed with a wavelength dispersive X-ray fluorescence spectrometer (SKYRAY INSTRUMENT EDX3600B). Health risk indication parameters (health risk index, daily intake of heavy metals and target health quotient) were evaluated.

The results obtained showed that the soil was polluted with Sn, Sb, Fe, Pb, Cd and Zn. The concentration of Sn, Sb, Fe, and Zn were less than the maximum allowable limit of 200mg/kg, 36mg/kg, 20mg/kg and 300 mg/kg respectively set for soils used for crop production. The concentration of Pb and Cd were lower than the maximum allowable limits (100, 3mg/kg). The daily intake values of Sb and Sn through ingestion of these vegetables were found to be higher than the recommended oral reference doses (RfDs) of 0.0004mg/kg/day and 0.0003mg/kg/day respectively, while that of iron was lower than the RfDs for adult, but higher than the dose for children. Daily intakes of Cd and Zn were lower than the respective oral reference doses of 0.001 and 0.300 mg/kg/day, while that of Pb was higher than the oral reference dose of 0.0035mg/kg/day. The health risk index and target health quotient values were, respectively, greater than one, indicating that the ingestion of the vegetables might affect human health negatively. Children consuming vegetables from these locations in the study area were seen to be in greater danger of health risks than the adults

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ACRONYMS

HM	Heavy Metals
WHO	World Health Organization
TF	Transfer Factor
BCF	Bio-accumulation Factor
DIM	Daily Intake of Metal
HRI	Health Risk Index
THQ	Target Hazard Quotient
TTHQ	Total Target Hazard Quotient

CHAPTER ONE

INTRODUCTION

1.1 Background of Study

Heavy metal contamination of soil and edible parts of vegetables is a challenging environmental issue worldwide (Gupta et al., 2022a). Due to its toxicity and close connection to human health, heavy metal poisoning of typical townships or urban soils has drawn significant attention from the public and environmental researchers worldwide for the past few decades.(Adimalla, 2020).

Heavy metals are naturally occurring elements that can enter the environment through both natural processes and human activities. However, anthropogenic sources such as mining, industrial processes, and agricultural practices contribute significantly to the presence of heavy metals in soils. Due to their persistent nature and potential toxicity, heavy metals pose a significant threat to ecosystems and human health. Attention to HMs contaminated agricultural soils is vitally significant since soil is an essential resource for life, and it requires adequate protection from excessive HMs build-up. (Muhammad et al. 2021). Rapid industrial development and intensive agricultural practices have substantially increased the concentration of heavy metals (HMs) in our environment. (Hassan et al.2020) Among different industries, mining and smelting of non-ferrous metals are considered the main sources of HM pollutants in our environment. (Xing et al. 2020)

There has been increasing interest in determining heavy metal levels in public food supplied. However, their concentration in bio-available form is not necessarily proportional to the total concentration of the metal. (Nkwunonwo et al. 2020). The quality of ecosystem becomes altered, when heavy metals find their way, somehow, into it through human and natural activities. These activities are one of the most rising concerns of urbanization in developing countries like Nigeria, which result in the problem of solid, liquid and toxic waste management. Such waste may be toxic or radioactive. (Onibokun and Kumuyi, 1996; UNDP, 2006) These waste management problems include heaps of uncontrolled garbage, roadsides littered with refuse, streams blocked with rubbish, prevalence of automobile workshops and service stations, inappropriately disposed toxic waste and disposal sites that constitute a health hazard to residential areas (Adewole and Uchegbu, 2005; Rotich et al., 2006; Ebong et al, 2008).

Soil is the most significant component of the environment. However, it is the most undervalued, misused and abused of the earth's resources. (Gokulakrishnan and Balamurugan, 2010). Soil is equally regarded as the ultimate sink for the pollutants discharged into the environment (Shokoohi et al. 2009). Soil contamination has become a serious challenge in all industrialized areas of the country. Almost all plants and animals depend on soil as a growth substrate for their sustained growth and development. In many cases, the preservation of life in the soil matrix is negatively affected by the presence of deleterious substances or contaminants. These organic and inorganic form of contaminants enter the soil as a result of the disposal of industrial effluents (Gowd et al. 2010). The contamination of soils with heavy metals in toxic concentrations adversely affects not only soils and plants but also poses risks to human health (Murugesan et al. 2008).

1.2 Statement of the Problem

Heavy metals in soils and crops can pose a risk to human health. The accumulating potential of heavy metals in vegetables from soil and the likelihood of non-carcinogenic health concerns via the ingestion of these vegetables have been analyzed (Gupta et al. 2022a)

One of the challenges resulting from the increased usage of fertilizers and other chemicals to meet the rising need for food production for human consumption is heavy metal pollution. The population's health risk assessment for heavy metals is a very effective technique since it may provide information about potential dangers from heavy metal contamination of soils and vegetables. The health risk assessment methods created by the United States Environmental Protection Agency (US EPA) have been applied to study the possible health dangers of heavy metals in soils growing vegetables (X. Liu et al. 2013).

The problems of heavy metals in soils and vegetables and its potential health risks can be summarized as follows:

1. Heavy metals in soils can accumulate in vegetables, posing a risk to human health.
2. The bio-concentration factor (BCF) of heavy metals from soils to vegetables has been computed to determine the ratio of the concentration of each heavy metal in the vegetable's edible portion to that in the soil.
3. The accumulation potential of heavy metals in vegetables from soil and the possibility of non-carcinogenic health risks via the consumption of these vegetables have been assessed.
4. The health risks due to exposure to heavy metals in the vegetable soil of facilities and ingrown vegetables through different exposure pathways have been assessed.

5. The health risk assessment methods developed by the United States Environmental Protection Agency (US EPA) have been employed to explore the potential health hazards of heavy metals in soils growing vegetables.

7. The concentration of different metals in agricultural soil and vegetables grown on those soils has been investigated to evaluate the possible health risks to the human body through food chain transfer.

1.3 Aims and objectives

The aim of this study is to determine the heavy metals found in the soil and vegetables in second cemetery, Iyakpen, Benin City, and to determine the health risk they pose to consumers.

The objectives of this study are as follows;

1. To clarify the level of accumulating heavy metals and their influencing causes/factors.
2. To determine the concentration of heavy metals in soils and vegetables collected from the cemetery and compare them with standard levels.
3. To assess the concentration of heavy metals in some soils and vegetables and evaluate the potential human health risks associated with their consumption.
4. To compute the daily metal intake (DIM), health risk index (HRI), target health quotient (THQ) and the total target health quotient (TTHQ) parameters.

1.4 Scope of study

Research on the buildup of heavy metals in soils has increasingly grown as facilities for the vegetable sector have developed quickly. According to several studies, the excessive use of vegetable land, fertilizer, and a high cropping index led to an increase in the level of heavy metals, which has contributed to the reduction in soil quality. Numerous studies have revealed the passage of contaminants from the soil into the food chain, jeopardizing the health of locals. Due to the accumulation of heavy metals, which is dangerous for food safety and human health, the problem of diminishing soil quality is linked to metal contamination in sewage irrigation regions, industrial areas, e.t.c.

As a result, analysis of soil and vegetable samples will be done to identify the amount of heavy metals present and to assess the possible adverse health effects associated with their use. Parameters such as Daily Intake of Metal (DIM), Health Risk Index (HRI), Target Hazard Quotient (THQ) and Total Target Hazard Quotient (TTHQ) will be computed. The study will also look at ways to minimize the levels of heavy metals in soils and vegetables, such as using appropriate agricultural practices and soil remediation methods. Also, the heavy metals present in the soil and vegetables will be determined using a wavelength dispersive X-ray fluorescence spectrometer, at the advanced material laboratory, a subsidiary of the National Agency for Science and Environmental Infrastructure (NASENI) Ondo Road, Akure, Ondo State, Nigeria. Sieve, tray, oven, pestle and mortar will be used for the analysis of the sample before testing. The study will enhance knowledge of the problem and offer important insights for environmental engineers and decision-makers to create practical countermeasures to the health concerns brought about by heavy metal contamination of the environment and agricultural systems.

1.5 Justification of study

It has been established that high industrial and waste disposal activities contribute to high levels of heavy metals in the environments. Plants grown around such areas are likely to absorb these metals either from the soil through the roots or from atmospheric contaminants through the leaves (Fifield and Haina, 1997). Heavy metal pollution of the environment, even at low levels, and their resulting long-term cumulative health effects are among the leading health concerns all over the world. Heavy metals are known as non-biodegradable and persist for long durations in aquatic as well as terrestrial environments. They might be transported from soil to ground waters or may be taken up by plants, including agricultural crops (Oluyemi et al., 2008).

World Health Organization (WHO) estimates that about a quarter of the diseases facing mankind today occur due to prolonged exposure to environmental pollution (Prüss-Üstün and Corvalán, 2006; Kimani, 2007).

Based on the cumulative, persistent and toxic effects of heavy metals as a result of consumption of leafy vegetables and fruits, there is a need to analyze these soils and vegetables to ensure that the levels of these trace elements meet the agreed international requirements.

Therefore, the justifications for conducting this study are to contribute to scientific knowledge, protect human health, encourage environmental stewardship, guide policy and regulation development, and ensure agricultural sustainability. We can make substantial progress toward establishing an ecosystem that is safer and more sustainable for both the current and future generations by addressing the health concerns and heavy metal assessment in soils and vegetables.

CHAPTER TWO

2.1. ENVIRONMENTAL POLLUTION

According to the World Health Organization (WHO), Pollution is the introduction of harmful materials into the environment. These harmful materials are called pollutants. Pollutants can be natural, such as volcanic ash. They can also be created by human activity, such as trash or runoff produced by factories. Pollutants damage the quality of air, water, and land. Environmental pollution caused by heavy metals is on the rise along with the increase in the use of chemicals in industries and agriculture. Such pollution is apparent in streams and lakes and in ground water, which is replenished directly from surface water (Huget et al., 2009).

Pollution of water and soils by heavy metals is an emerging concern in industrialized countries. Since the advent of development through mining and smelting, metallurgical industries, sewage, warfare, and tanning, the survival of plants and animals are much affected (Xi et al., 2009). Environmental pollution has become a major concern of developing countries in the last few decades. There is a growing sense of global urgency regarding the pollution of our environment by an array of chemicals used in various activities (Palaniappan et al., 2009).

The quality of life on earth is linked to the overall quality of the environment (Hsua et al., 2006).

2.1.1 TYPES OF ENVIRONMENTAL POLLUTION

2.1.2. LAND/SOLID WASTE POLLUTION

Land pollution is one of the major forms of environmental pollution (Khan, 2004). Improper disposal and management of solid waste is one of the major causes of environmental pollution (Kimani, 2007). According to Rushbrook (1994), most of the solid industrial waste containing heavy metals is disposed of, without pretreatment in open dumps and various surfaces.

2.1.3 WATER POLLUTION

The WHO states that one sixth of the world's population approximately 1.1 billion people do not have access to safe water and 2.4 billion lack basic sanitation (EPHA, 2009). Polluted water contains Industrial discharged effluents, sewage water, rain water pollution (Ashraf et al, 2010) and pollutants from agriculture or domestic sources cause damage to human health and the environment (European Public Health Alliance, 2009). It also affects the health and quality of soils and vegetation (Carter, 1985).

2.1.4 AIR POLLUTION

Polluted air contains at least one or more toxic substances, pollutant, or contaminant that creates a hazard to general health. Health and Energy, (2007). The main pollutants found in the air we breathe in includes, particulate matter, lead, ground-level ozone, heavy metals, sulphur dioxide, benzene**,** carbon monoxide and nitrogen dioxide (EPHA, 2009).

2.2 HEAVY METALS

According to chemical properties, heavy metals are elements that exhibit metallic properties and are defined based on density, atomic number or atomic weight, chemical properties or toxicity. According to chemical properties, heavy metals are elements that exhibit metallic properties and are defined based on density, atomic number or atomic weight, chemical properties or toxicity.

The term heavy metal refers to any metallic chemical element that has a relatively high density and is hazardous or poisonous at low concentrations. Examples of heavy metals include mercury (Hg), cadmium (Cd), arsenic (As), chromium (Cr), thallium (Tl), and lead (Pb).

Heavy metals are natural components of the Earth's crust. They cannot be degraded or destroyed. To a small extent, they enter our bodies via food, drinking water, and air. As trace elements, some heavy metals (e.g. copper, selenium, zinc) are required to maintain the metabolism of the human body. However, at higher concentrations, they can cause to toxicity. Heavy metal poisoning may arise, for instance, through drinking-water pollution (e.g. lead pipes), high atmospheric concentrations near emission sources, or absorption via the food chain.

Heavy metals are harmful because they tend to bio-accumulate. Bioaccumulation refers to an increase in the concentration of a chemical in a biological organism over time, compared to the chemical's concentration in the environment. Compounds accumulate in living organisms any time they are taken up and stored quicker than they are broken down (metabolized) or expelled.

Heavy metals can infiltrate soils and vegetables by industrial and consumer waste, or even from acidic rain breaking down soils and releasing heavy metals into soils, streams, lakes, rivers, and groundwater.(*Heavy Metals - Lenntech*, n.d.)

Rapid industrial development and intensive agricultural practices have substantially increased the concentration of heavy metals (HMs) in our environment. (Hassan et al., 2020)

2.2.1 TYPES OF HEAVY METALS AND EFFECTS OF HEAVY METALS ON THE ENVIRONMENT

Moving on, we are going to describe the impact of heavy metals in the environment. The three most pollutant heavy metals are Lead (Pb), Cadmium (Cd), and Mercury (Hg).

2.2.1.1 TIN (Sn)

Tin is highly resistant to corrosion and regularly used for coating other metals like steel. This is commonly seen when tin is used to line the insides of beverage cans and food containers. Regardless of the frequent use of tin, there have been concerns about the safety of tin. Research has shown the negative impacts of tin on human health. High concentrations of tin are present in the air and soil samples where hazardous wastes are found. Tin dusts can irritate the skin and delicate tissues especially in the respiratory system and eyes. High exposure to tin could also lead to occupational lung disease. Metallic tin is not very toxic due to its poor gastro-intenstinal absorption. Large amounts of inorganic tin compounds can lead to liver and kidney problems, anemia and stomachaches (ASTDR 2005).

2.2.1.2. ANTIMONY (Sb)

Antimony is a metal used in the compound antimony trioxide, a flame retardant. It can also be found in batteries, pigments, and ceramics and glass. Exposure to high quantities of antimony over short periods of time causes nausea, vomiting, and diarrhea. There is limited information on the effects of long-term antimony exposure, however it is a probable human carcinogen.(*Heavy Metals - Lenntech*, n.d.)

Among different HMs, antimony (Sb) has emerged as a serious toxic metal, and its concentration is also increasing in our soil owing to anthropogenic activities. (Ma et al.,

2019) The excessive intake of Sb in humans through eating Sb-contaminated foods can cause cancer, liver, and cardiovascular diseases (Herath et al., 2017; Hajiani et al., 2016). Due to its rising concentration and toxic effects, Sb has been listed as a top pollutant by the European Union and USA environmental protection agency (Feng et al., 2013)

It is considered that Sb concentration in soils greater than 150 mg/kg causes damage to plants. (Feng et al., 2013). It affects all plant processes ranging from germination, growth, development, photosynthesis, and induced reactive oxygen species (ROS) production; all these changes induce a serious reduction in plant growth. (Remans et al., 2012; Zeng et al., 2015) Sb present in soil solution is readily absorbed by plant roots, which, in turn, reduces growth, photosynthesis, and synthesis of proteins and metabolites (Feng et al., 2012). The high concentration of Sb in soils and sediments is toxic to ecosystems and the human health (Natasha et al., 2018). The acceptable levels of Sb in water and soil are 0.020 mg L-^{1} and 36 mg kg^{-1}, respectively (Guo et al., 2009) and an increase in the Sb concentration above these levels causes serious damage to plants and humans. Plants have developed a promising antioxidant system to cope with the damage of Sb toxicity. (Bolan et al., 2022)

2.2.1.3 CADMIUM (Cd)

Cadmium is one of the most hazardous metals owing to its high toxicity and serious extent of bioaccumulation. (P. Singh et al., 2020; Q. Ma et al., 2022b). Cd is classified as group 1 carcinogen and ranked 7th in the list of 20 most toxic metals. (Jaishankar et al., 2014) The toxicity of Cd affects the human body adversely, and it accumulates in the kidneys and causes emphysema, renal tubular damage, and kidney stones (Mahajan & Kaushal, (2018) It is released to the environment through natural and anthropogenic methods. Natural methods include weathering of Cd-containing rocks, forest fires, volcanic eruptions, and wastewater which are the principal means. (Liu et al., 2013); (Manzoor et al., 2019) Anthropogenic activities are a source of Cd contamination, mainly including metallurgical works, mining, electroplating, paints, combustion emissions, and excessive use of fertilizers and pesticides.

Since the 1970s, there has been an established interest in possible exposure of humans to Cd through their food consumption. Concerns regarding this route (agricultural crops) led to research on the possible consequences of applying sewage sludge (Cd-rich biosolids) to soils used for crops meant for human consumption, or of using cadmium-enriched phosphate fertilizer (Campbell, 2006).

Cadmium in the body is known to affect several enzymes. It is believed that the renal damage that results in proteinuria is the result of Cd adversely affecting enzymes responsible for reabsorption of proteins in kidney tubules.

Cadmium also reduces the activity of delta-aminolevulinic acid synthetase, arylsulfatase, alcohol dehydrogenase, and lipoamide dehydrogenase, whereas it enhances the activity of delta-aminolevulinic acid dehydratase, pyruvate dehydrogenase, and pyruvate decarboxylase (Manahan, 2003). The most spectacular and publicized occurrence of cadmium poisoning resulted from dietary intake of cadmium by people in the Jintsu River Valley, near Fuchu, Japan. The victims were afflicted by itai itai disease, which means ouch, ouch in Japanese. The symptoms are the result of painful osteomalacia (bone disease) combined with kidney malfunction. Cadmium poisoning in the Jintsu River Valley was attributed to irrigated rice contaminated from an upstream mine producing Pb, Zn, and Cd. The major threat to human health is chronic accumulation in the kidneys leading to kidney dysfunction. Food intake and tobacco smoking are the main routes by which Cd enters the body. (Manahan, 2003).

2.2.1.4 ZINC (Zn)

Zinc is an essential nutrient in humans and animals. It is necessary for the function of a large number of metallo-enzymes such as alcohol dehydrogenase, alkaline phosphatase, carbonic anhydrase, leucine aminopeptidase, superoxide dismutase, and deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) polymerase.

When high levels of zinc are ingested into the body, inhibition of copper absorption through interaction with metallothionein at the brush border of the intestinal lumen occurs. Both copper and zinc appear to bind to the same metallothionein protein. However, copper has a higher affinity for metallothionein than zinc and displaces zinc from metallothionein protein. Copper complexed with metallothionein is retained in the mucosal cell, relatively unavailable for transfer to plasma, and is excreted in the feces when the mucosal cells are sloughed off. Thus, an excess of zinc can result in a decreased availability of dietary copper, and the development of copper deficiency. (Gyorffy and Chan, 1992).

Moreover, zinc deficiency has been associated with dermatitis, anorexia, growth retardation, poor wound healing, hypogonadism with impaired reproductive capacity, impaired immune function, and depressed mental function; increased incidence of congenital malformations in infants has also been associated with zinc deficiency in the mothers. (Sandstead, 1981).

2.2.1.5 COBALT (Co)

Cobalt is a component of cyano-cobalmin (vitamin B12), and is essential for the body. Cobalt has been identified in most tissues of the body, with the highest concentrations found in the liver (ATSDR, 2004). It enters the air through the burning of oil and cobalt compounds that are used as colorants in glass, ceramics, and paints, as catalysts, and as paint driers. Cobalt compounds are also used as trace element additives in agriculture and medicine (ATSDR, 2004). After it enters the air cobalt is associated with particles which will settle to the ground within few days. Some of the compounds may then settle in water, food and drinking water and these are the largest sources of exposure to the general population. (Udeh, 2004).

2.2.1.6 CHROMIUM (Cr)

Chromium (Cr) is one of the less common elements and does not occur naturally in elemental form, but only in compounds. Chromium is mined as a primary ore product in the form of the mineral chromite, FeCr2O4. Major sources of Chromium contamination include releases from electroplating processes and the disposal of Cr containing wastes. (Smith et al., 1995).

Chromium (VI) is the form of Cr commonly found at contaminated sites. Chromium (VI) can be reduced to Cr (III) by soil organic matter, S2- and Fe2+ ions under anaerobic conditions often encountered in deeper groundwater. Major Cr (VI) species include chromate (CrO42-) and dichromate (Cr2O72-). Chromate and dichromate also adsorb on soil surfaces, especially iron and aluminum oxides (Smith et al., 1995).

Chromium mobility depends on sorption characteristics of the soil, including clay content, iron oxide content, and the amount of organic matter present. Chromium can be transported by surface runoff to surface waters in its soluble or precipitated form. Soluble and un-adsorbed chromium complexes can leach from soil into groundwater. Chromium is associated with allergic dermatitis in humans. (Scragg, 2006).

2.2.1.7 LEAD (Pb)

Lead is a toxic element that can be harmful to plants. However, plants usually show ability to accumulate large amounts of lead without visible changes in their appearance or yield. Lead is a well-known neurotoxin. Impairment of neurodevelopment in children is the most critical effect. Exposure in uterus, during breastfeeding and in early childhood may all be responsible for the effects. Lead accumulates in the skeleton and its mobilization from bones during pregnancy and lactation causes exposure to fetuses and breastfed infants (ATSDR, 2007). In many plants, lead accumulation can exceed several hundred times the threshold of maximum level permissible for human. (Wierzbicka, 1995). It has been suggested that lead on a cellular and molecular level may permit or enhance carcinogenic events involved in DNA damage, DNA repair, and regulation of tumor suppressor and promoter genes. (Silbergeld, 2003). Plants grown in lead-contaminated soils accumulate low levels of lead in the edible portions of the plant from adherence of dusts and translocation into the tissues. (Finster et al., 2004).

2.2.1.9 MERCURY (Hg)

Mercury is an environmental toxin that produces a wide range of adverse health effects in humans. (Guzzi and La Porta, 2008). The most common natural forms of mercury found in the environment are metallic mercury, mercuric sulfide (cinnabar ore, mercuric chloride, and methyl-mercury). Each of them has its own profile of toxicity (ATSDR, 1999).

Methyl-mercury is of particular concern because it can build up in certain edible freshwater and saltwater fish and marine mammals to levels that are many times greater than levels in the surrounding water. Metallic and inorganic mercury enters the air from mining deposits of ores that contain mercury, from the emissions of coal fired power plants, from burning municipal and medical waste, from the production of cement, and from uncontrolled releases in factories that use mercury. Metallic mercury is a liquid at room temperature, but some of the metal will evaporate into the air and can be carried long distances. In air, the mercury vapor can be changed into other forms of mercury and can be further transported to water or soil in rain or snow. (Wiwanitkit, 2009)

Inorganic mercury may also enter water or soil from the weathering of rocks that contain mercury, from factories or water treatment facilities that release water contaminated with mercury, and from incineration of municipal garbage that contains mercury. It can enter and accumulate in the food chain. The form of mercury that accumulates in the food chain is methyl-mercury. (Balshaw et al., 2007; Wiwanitkit, 2009).

Symptoms of mercury poisoning include permanent damage to the brain and kidneys, personality changes (irritability, shyness, and nervousness), tremors, changes in vision, deafness, muscle incoordination, loss of sensation, and difficulties with memory (ATSDR, 1999).

2.2.1.10 IRON (Fe)

Iron is the second most abundant metal on the earth surface (EPA, 1993). It is an important element for the growth and survival of almost every living thing (Valko et al., 2005). Iron can be sourced from anthropogenic sources such as mining, and natural sources as iron ore found in the earth crust. Excessive intake of iron could lead to constipation, abdominal pain, vomiting, diarrhea, stomach upset, convulsions, ulcers and ultimately death.

2.3 LITERATURE REVIEW OF SOME WORKS ON HEAVY METALS

Human health is of the utmost importance. Heavy metals sometimes pose a serious risk to our health and this has been largely ignored until recent years.

Studies on heavy metal accumulation in food crops and agricultural soils carried out globally over the past 10 years have shown a disturbing trend of heavy metal concentrations surpassing maximum allowed limits in food crops and farm soils.

This literature will look at some of the studies on how heavy metals affect our health through soils and vegetables.

Atikpo & Owamah, (2022) talked about Health risk and heavy metal assessment in soils and vegetables sourced from Amaonye forest Farmland, Eastern Nigeria. This study investigated the concentrations of cadmium (Cd), lead (Pb) and zinc (Zn) in soil and vegetables, and the associated health risk of ingesting vegetables from Amaonye-Ishiagu farming zone, Ebonyi State, Nigeria. Soil samples from 0 to 20 cm depth were analyzed using atomic absorption spectrometer for Cd, Pb and Zn and modeled with geo-statistical extension of the ArcGIS. Edible parts of five leafy vegetables commonly found in the regional markets were randomly harvested from ten (10) farms and tested for the metals. Risk indication parameters (health risk index, daily intake of heavy metals and target health quotient) were evaluated. Results obtained showed that the soil was polluted with Pb, Cd and Zn as their concentrations were above the respective maximum allowable limits (100, 3 and 300 mg/kg) set for soils used for crop production.

Xu et al., (2022) studied the Heavy Metal Pollution and Health Risk Assessment of Vegetable–Soil Systems of Facilities Irrigated with Wastewater in Northern China. The health risks associated with various exposure paths to heavy metals found in facility and ingrown vegetable soil were assessed. To examine the soil quality, spatial interpolation and a potential ecological risk assessment were used. To examine the capacity of various portions of various vegetables to absorb and transport Cd, Cu, Pb, and Zn, bioaccumulation factors (BCFs) were utilized. The findings suggested that Cd poses the most serious contamination among the four metals in the soil of facilities in the Xi River sewage irrigation area by having an average concentration that was 1.82 times higher than the standard standards and accumulated by 11 times.

Mao et al.,(2023) In order to comprehend the heavy metal (Cd, Cr, and Pb) pollution situation and exposure risk of the soil and vegetables in Jinhua City, soil-vegetable samples obtained from three different districts of the city were thoroughly analyzed, and the risks of heavy metal concentration in the soil and vegetables were assessed using the single pollution index, Nemerow pollution index, Hakanson potential ecological index, and a health risk assessment. The findings show that: (1) Cd is the principal pollutant in the soil in Jinhua City, and that leafy vegetables had the highest BCF of heavy metals among vegetables, followed by rootstalk vegetables and solanaceous vegetables. (2) Heavy metals caused some little environmental damage, and the overall ecological risk of soil heavy metals in the sampling region was minimal. (3) (3) Non-carcinogenic risks are more prevalent in children; the primary risk factor is Cr (HQCr = 0.74). More than 90% of the vegetables in the sample had a potential for cancer, adults were more likely to experience carcinogenic risks, and Cd was the main source of this risk (TCR = 4.34 104). Therefore, in our study region, Cd is the primary cause of soil pollution that can potentially increase the risk of cancer through the enrichment of vegetables, whereas Cr is the primary cause of the non-carcinogenic risk of leafy vegetables.

In order to determine the levels of heavy metals (As, Cd, Cu, Hg, Pb, and Zn) in soils and food biomass crops as well as to calculate the potential health risks of metals to people through consumption of contaminated food biomass crops from Shifang, a periurban agricultural area in the Chengdu Plain, Sichuan, China.(Q. Liu et al., 2022) carried out this study. The findings showed that the soils had been accumulating significant amounts of heavy metals, particularly Cd, with a mean of 0.84 mg kg1, which is roughly six times higher than background values and 98% of which exceeded the pollution warning threshold of the China Soil Environmental Quality Standards. 78% of the grain component as a whole failed to meet the Cd national food standard.

In this study by Gupta et al., (2022b) on the Investigation of Heavy Metal Accumulation in Vegetables and Health Risk to Humans From Their Consumption, the accumulated amounts of cadmium (Cd), lead (Pb), nickel (Ni), cobalt (Co), zinc (Zn), copper (Cu), and manganese (Mn) in soil, coriander, onion, and tomato were measured. The samples were taken from agricultural areas in Jhansi, India. The bio-concentration factor and non-carcinogenic health risks were also evaluated to understand the potential for heavy metals in soil to accumulate in vegetables and the probability of non-carcinogenic health concerns from consuming these vegetables. Before conducting an atomic absorption spectrometric analysis for the presence of heavy metals, the samples were digested using a di-acid solution.

The study by Osae et al.,(2023) on the Accumulation of heavy metals and human health risk assessment of vegetable consumption from a farm within the Korle lagoon catchment evaluated the levels of heavy metals in a variety of plants (including amaranth, spinach, eggplant, lettuce, cauliflower, and onion) and their corresponding soil from a farm within the watershed of the Korle Lagoon. They were evaluated for their health risks using the estimated daily intake (EDI), hazard quotient (HQ), and lifetime cancer risk (LCR). The highest level of heavy metals found in lettuce among the vegetables examined was over the recommended range. The findings also revealed the extent to which the research area's soil was polluted by heavy metals, as well as the potential dangers associated with eating vegetables grown there, for both adults and children, both of which were found to be carcinogenic and non-carcinogenic.

The study by Ullah et al.,(2022) on the Assessment of heavy metals accumulation in agricultural soil, vegetables and associated health risks looks at the identification, characterization, and evaluation of particular heavy metals in industrial wastewater (IWW) as well as various composite samples of soil and vegetables (onion, pumpkin, lady finger, and green pepper) gathered from particular agricultural fields irrigated with canals fed IWW in Mingora city of Swat (Pakistan). Results were compared to soil that had been irrigated with tube well water and crops that had been produced there. Atomic absorption spectrophotometry (AAS) and the wet digestion method were used to assess the buildup of heavy metals. Using the Monte Carlo simulation technique, the metal transfer factor (MTF) of heavy metals from soil to vegetables was also established in order to evaluate the possible health risk of the metals towards consumers. The levels of heavy metals observed in soil irrigated with IWW were higher than those found in soil irrigated with TWW.

In this study by Z. Wang et al., (2021) on the hazardous Heavy Metals Accumulation and Health Risk Assessment of Different Vegetable Species in Contaminated Soils from a Typical Mining City, Central China, soils, vegetables, and crops close to four typical mining and smelting zones were examined for the presence of five harmful heavy metals (HMs), including copper (Cu), chromium (Cr), lead (Pb), cadmium (Cd), and arsenic (As). To gauge the extent of the pollution, Nemerow's synthetical pollution index (Pn), Potential ecological risk index (RI), and Geo-accumulation index (Igeo) were utilized. The findings demonstrated that Cu, Cd, As, and Pb were severely polluting soils close to mining and metal smelting zones.

In 60 vegetable samples, irrigation water, and agricultural soil samples gathered from 5 farms in the Saudi Arabian suburbs near the Riyadh district, the amounts of Fe, Mn, Cu, Zn, Ni, Pb, and Cd were estimated. Furthermore, estimations were made for the soil pollution indices, the pollution load index and contamination factor (PLI, CF), the bioaccumulation factor (BAF), and the non-carcinogenic and carcinogenic risk indices (HQ, THQ, and ILCR). Except for Cd in soil, which exceeds allowable levels, both irrigation water and soil contained only the recommended amount of heavy metals. Fe > Mn > Zn > Cu > Ni > Pb > Cd was the order in which metal concentrations were observed to trend in agricultural soil and vegetables. An accumulation of metals was seen, according to a cluster analysis of the metal content of vegetables. The concentration of heavy metals was in the following order: leaves > roots > fruits > flowers > tuber. BAF values were 1.0, HQ values for Fe, Mn, Cu, Zn, and Ni were discovered to be 1, and estimated HQs for Pb and Cd were > 1, posing increased risk to both adults' and children's health. Comparing children to adults, THQ values were greater in the latter group. Cd levels over the threshold risk limit (>104) were found in all examined vegetable components and across all sampling sites, which is a major problem indicated by ILCR values, in a study by (Alturiqi et al., 2020) on health risk assessment of heavy metals in irrigation water, soil and vegetables from different farms in riyadh district, Saudi Arabia.

The purpose of this study by Muhammad et al., (2021) is to analyze the health risks and the level of heavy metal pollution in the vegetables grown at the Danbatta irrigation lands. In order to conduct the research, irrigation fields' soil, water, and grown vegetables had to be collected and their levels of heavy metal pollution had to be assessed. Samples were taken in Nigeria's Kano state's Danbatta irrigation areas. The research investigation lasted for a whole year. This study looks into the likelihood of heavy metal pollution and the health concerns connected to the vegetables grown in Kano state's Danbatta local government. This was accomplished by removing irrigation soil, water, and vegetables (onion, spinach, and lettuce) from the irrigation locations. The collected materials were then tested for many heavy metals, including Pb, Mn, Cu, Fe, and Zn and Co using atomic absorption spectrophotometry (AAS).

Ibiam et al., (2021) in his Assessment of Levels and Health Risks of Trace Metals in Soils and Food Crops Cultivated on Farmlands Near Enyigba Mining Sites, Ebonyi State, Nigeria, hypothesized that Dioscorea rotundata (white yam), Manihot esculenta (cassava), Telfariria occidentalis (fluted pumpkin leaves), and Arachi hypogea (groundnut) seeds cultivated on farmlands near mining site areas may have ongoing uptake of heavy metals from the soil that subsequently may pose health risks to consumers upon consumption of these food crops.

Also J Okereke, (2016) looked at Human Health Risk Assessment of Heavy Metal Contamination for Population via Consumption of Selected Vegetables and Tubers Grown in Farmlands in Rivers State, South-South Nigeria. The purpose of this study was to determine the levels of heavy metals (Pb, Ni, Cd, Cu, and Cr) in six types of commonly consumed vegetables, tubers, and agricultural soils in the communities of Alakahia and Eleme in the Nigerian state of Rivers. The Agilent FS240AA Atomic Absorption Spectrophotometer was used to check for heavy metals in the samples of vegetables, tubers, and soil. All of the plant samples that were taken from the two study sites had measurable levels of several of the heavy metals that were examined. The amounts of these elements in the plant samples ranged from 0.01-2.78 mg/kg. Dioscorea rotundata from the Alakahia site, however, revealed the highest level of chromium (1.26 0.05 mg/kg) among the various metals examined. The study sites' soil heavy metal concentrations were much below the allowable limits.

Babatunde et al., (2014) wrote about Assessment of Zn, Cu and Pb Contamination in Soils and Vegetables from Some Farmlands in Lagos Metropolis, Lagos, Nigeria. Investigated in this study are the levels of concentration of three heavy metals; Zn, Cu and Pb in some leafy vegetables viz., cockscomb (Celosia argentea), african spinach (Amarathus viridis), , jute plant (Corchorus olitorus) and lettuce (Lactuca capensis) from four farmlands designated as Idi - araba, Isolo, Owode - Onirin and Badore in Lagos Metropolis. According to this research, customers may not experience any health risks from eating veggies that were picked up straight from the study locations.

Nwadiuto Amadi Obasi et al., (2012) spoke about the Evaluation of Potential Dietary Toxicity of Heavy Metals of Vegetables. In order to assess the possible dietary toxicity, the experiment involved measuring the quantities of lead (Pb), cadmium (Cd), nickel (Ni), and mercury (Hg) in soil and frequently produced or sold vegetables in southeastern Nigeria. Vegetables were examined to establish the concentrations of accumulated metals to which humans are exposed. The effects of transfer factors of heavy metals from soil locations were determined.

Another study by Saeed Zango et al., (2013) in Wassa-Amenfi-West District of Ghana discovered that heavy metal concentrations in mining areas were higher than that in non - mining areas but still both pose a serious health risk to the general population.

X. Liu et al., (2013) In his research on Human health risk assessment of heavy metals in soil–vegetable system in China, concluded that more effective controls should be focused on Cd and Cr to reduce heavy metals pollution in this study area.

While conducting a research on the use of fertilizers in growing of vegetables Mir et al.,(2020) discovered that phosphate fertilizers are the main source of soil heavy metals pollution. This pollution is because of the presence of cadmium as an impurity in phosphate rocks

Also, carrying out an assessment on the use of vegetables and soils in waste water irrigated areas of Beijing-Tianjin city cluster, China, Y. Wang et al., (2012) experimental results showed that the health risks of heavy metals exposure through consuming vegetables were generally assumed to be safe.

In a study of the accumulation of Heavy Metals in Vegetable Species Planted in Contaminated Soils and the Health Risk Assessment in Shizhuyuan area of China Zhou et al.,(2016) indicated that the low accumulators (melon vegetables) were suitable for being planted on contaminated soil, while the high accumulators (leafy vegetables) were unsuitable.

Inhabitants of Bogra District, northern Bangladesh who consume contaminated vegetables from the fields of the riverside, are exposed chronically to metal pollution with carcinogenic and non-carcinogenic risks from a study carried out by (Islam et al., n.d.)

Health risk assessment results from the research carried out on Bioaccumulation of antimony and arsenic in vegetables and health risk assessment in the super-large antimony-mining area, China by Zeng et al., (2015) showed that the chronic daily intake (CDI) and hazard quotient (HQ) values of heavy metals such as Sb were over the safe limit recommended by FAO and WHO, indicating that long-term consumption of vegetables from the surrounding soils of XKS mine may bring health risks to residents.

Health risk assessment of the Occurrence and health risks of heavy metals in plastic-shed soils and vegetables across China by J. Liu et al., (2021) revealed that enough attention should be paid to the cancer risk posed by ingesting the leafy vegetables grown in PS.

In his research on Human health risk assessment: Heavy metal contamination of vegetables in Bahawalpur, Pakistan, Qadir et al., (2016) concluded that the quality of vegetables irrigated with sewage water is poor and not fit for human health, evident from the high concentration of Pb, Cd and Cr. Urgent measures are required to prevent consumption and production vegetables irrigated with of sewage water in the study area.

In a Heavy metals health risk assessment for population via consumption of vegetables grown in old mining area; a case study: Banat County, Romania, Harmanescu et al., (2011a) suggest that heavy metals are present in the consumption of some vegetables (particularly parsley, carrot and cabbage and less for lettuce, cucumber and green beans) in these locations.

CHAPTER THREE

METHODOLOGY

3.1 STUDY AREA

The study area is located within latitude 6°20'29" North and longitude 5°36'28" East, in Iyakpen, Oredo Local Government Area, Edo State.

Figure 3.1 location map of 2nd cemetery, Benin city, Edo state, Nigeria

3.2 SAMPLE COLLECTION

A systematic soil sampling was done in the field to determine the level of heavy metals concentrations in order to determine the health risk assessments of these metals. (Pias et al., 2019) (Lawrence et al., 2020). Leafy vegetables comprising Bitter leaf (Vernonia amygdalina), sweet potato (Ipomoea batatas), orange (Citrus sinensis) and mango (Mangifera indica) were randomly collected from around the cemetery and transported to University of Benin Civil engineering laboratory, Benin City, Nigeria, for sample preparation. The vegetables were washed with distilled water to remove any traces of dirt, and the soil samples were air-dried, powdered, and sieved. (Rehman et al. 2017). The washed vegetable leaves were separated, air-dried and further dried in oven for 72 h at 65 °C to attain constant weight. The dried leaves were pounded with a mortar and pestle and converted to powder and stored each in a plastic bag for analysis. (Rehman et al. 2017 ; Muhammad et al., 2021)).

TABLE 3.1 LOCATION OF SOIL AND VEGETABLE SAMPLES

Location	**Latitude**	**Longitude**	**Elevation**
A	6.340900	5.609597	95 yards
B	6.340983	5.608042	96 yards
C	6.341360	5.606835	93 yards
D	6.342380	5.606615	97yards
E	6.340983	5.605820	92 yards
F	6.339733	5.607698	93 yards
G	6.340108	5.607962	93 yards
H	6.339925	5.609052	72 yards

I	6.341767	5.609190	98 yards

3.3 DETERMINATION OF HEAVY METALS

The experimental studies of both soil and vegetable samples were performed at the Nanotechnology and advanced material laboratory, a subsidiary of National Agency for Science and Environmental Infrastructure (NASENI) Ondo Road Akure, Ondo State, Nigeria, using a wavelength dispersive X-ray fluorescence (WDXRF) spectrometer (SKYRAY INSTRUMENT EDX3600B). The X-ray fluorescence spectrometer applies XRF technology to conduct fast and accurate analysis of complex composition. The samples were dried in an oven at 80 ° C for 18-20 hours. Each sample was repeatedly ground to less than a 50 m sieve size, weighed to a range of 100 to 200 mg, and then used to make 2.5 cm diameter pellets in a pellet pressing machine under a pressure of 10 to 15 tons. The pellets were analyzed using XRF spectroscopic technology. For a total of 2500 seconds, each pellet received primary radiation from a Cd-109 radioactive source. Two irradiations of the sample alone and the sample with a molybdenum target on top were carried out for each pellet. The absorption adjustments were then computed using these two data. The NaI(Tl) detector picked up the distinctive X-rays that the sample's elements emitted. In order to detect elements as effectively as possible, the measurements were carried out in vacuum using various filters (between the source and sample). For Cr, Mn, Fe, Co, Ni, Cu, and Zn, a 0.05-mm-thick Ti filter was placed in front of the source with an applied voltage of 14 kV and an applied current of 900 mA. A Fe filter with a thickness of 0.05 mm was used for higher Z elements like Pb, Bi, Ag, and at a voltage of 37 kV and a current of 45 mA. The system's inbuilt "nEXt" software, which runs on the Windows NTTM operating system, was used to quantitatively analyze the X-ray fluorescence spectra. In both qualitative and quantitative analysis, acquiring spectra was the first and one of the most crucial tasks. The spectrum capture technique uses acquisition parameters to establish the spectrum profile and parameters. They were selected in order to increase the number of counts for the important elements.

3.4 EQUATIONS OF HEALTH RISK ASSESSMENT

3.4.1 TRANSFER FACTOR

By applying Eq 3 previously applied in (Tasrima et al. 2015; Zhou et al. 2016; Ramteke et al. 2016) and Rehman et al. 2017), It was possible to calculate the transfer factor, bioconcentration factor, or bioaccumulation factor, which is the ratio of HM in soil to HM in plants.

$$\mathbf{BCF} = \frac{C_{vegetable}}{C_{soil}} \qquad \text{Eq. (3.1)}$$

Where;

$C_{vegetable}$ = concentration of metals in vegetable (mg/kg)

C_{soil} = concentration of metals in soil (mg/kg)

3.4.2 DAILY INTAKE OF METAL (DIM)

The daily intake of metals (DIM) was developed to approximate the average daily metal loading into the body system of a consumer with a given body weight. The relative phyto-availability of metal will be affected by this. This can simply determine the potential ingestion rate of a certain metal but does not consider the metals' potential metabolic ejection. The DIM was determined using Eq. (4) (Khan et al. 2010; Jan et al. 2010; Ramteke et al. 2016; Rehman et al. 2017; Fonge et al. 2021).

$$\textbf{DIM} = \frac{Cm \times Cf \times Dvi}{Baw} \qquad \text{Eq. (3.2)}$$

Where Cm = metal concentration in vegetables (mg/kg)

Dvi = daily vegetable intake

Baw = average body weight (kg)

And Cf = conversion factor of vegetables from fresh weight to dry weight. (Jan et al. 2010; Ramteke et al. 2016; Edogbo et al. 2020). Cf value of 0.085 used by (Rehman et al. 2017) and Edogbo et al. 2020) was adopted in this study. Also, D_{vi} and B_{aw} values used were 205g/p/d (gram/person/day) and 70kg for adults respectively, and 150g/p/d and 20kg respectively for children

3.4.3 HEALTH RISK INDEX (HRI)

Calculating the level of human exposure to a heavy metal by tracking the path the pollutant takes before entering the human body is important to determine the risk that metal poses to human health. There are numerous heavy metal exposure pathways that rely on the recipients' exposure to polluted soil and crops. Vegetables with greater concentrations of heavy metals are consumed by the receptor population, putting human health at risk. (Rehman et al. 2017)

$$\textbf{HRI} = \frac{\textbf{DIM}}{\textbf{RfD}} \qquad \text{Eq. (3.3)}$$

Where DIM is the daily metal intake in mg/kg

RfD represents reference oral dose.

RfD values of 0.001, 0.0035 and 0.300 mg/kg/day were adopted in this study (Shah et al. 2012).

3.4.4 TARGET HAZARD QUOTIENTS

The hazard quotient (HQ), reflects the non-carcinogenic risk level of the contaminants. The target hazard quotient was determined from Eq. (6) (Wang et al. 2005; Storelli et al. 2008; Manea et al. 2020; Haque et al. 2021).

$$\mathbf{THQ}=\frac{\mathbf{Ef\times Ed\times\ FIR\times C\times\ 10-3}}{\mathbf{RfD\times Wab\times Ta}}$$ Eq.

(3.4)

where E_f is 350 days/year exposure frequency; Ed is 54 years exposure duration; FIR is the vegetable ingestion rate (150 g/p/d and 200 g/p/d for children and adults, respectively); RfD values are 0.001, 0.0035 and 0.300 mg/ kg/day for Cd, Pb and Zn, respectively; Wab is average body weights (20kg and 70kg for children and adults, respectively); and Ta (Ed×365 days/year) is non-carcinogens average exposure time. Exposure will likely result to noticeable negative health effects if THQ is greater than one (Chauhan et al. 2014; Zhou et al. 2016).

3.4.5 TOTAL TARGET HAZARD QUOTIENTS

This is the sum total of all the target hazard quotient. The TTHQ was determined with the formula in Eq. (7) (Storelli et al. 2008); Manea et al. 2020; Haque et al. 2021). If the total diet THQ (TTHQ) > 1, ingestion of metals though vegetables will likely result to adverse health effects (Zhou et al. 2016; Edogbo et al. 2020)

$$\mathbf{TTHQ} = \sum_{i=1}^{n} (\mathbf{THQ})$$ Eq.

(3.5)

CHAPTER FOUR

RESULTS AND DISCUSSION

This chapter encompasses the presentation, analysis and discussion of results gotten from the laboratory analysis of the different soil and vegetable samples collected from each location at second cemetery.

4.1 XRF RESULTS OF HEAVY METALS STUDY

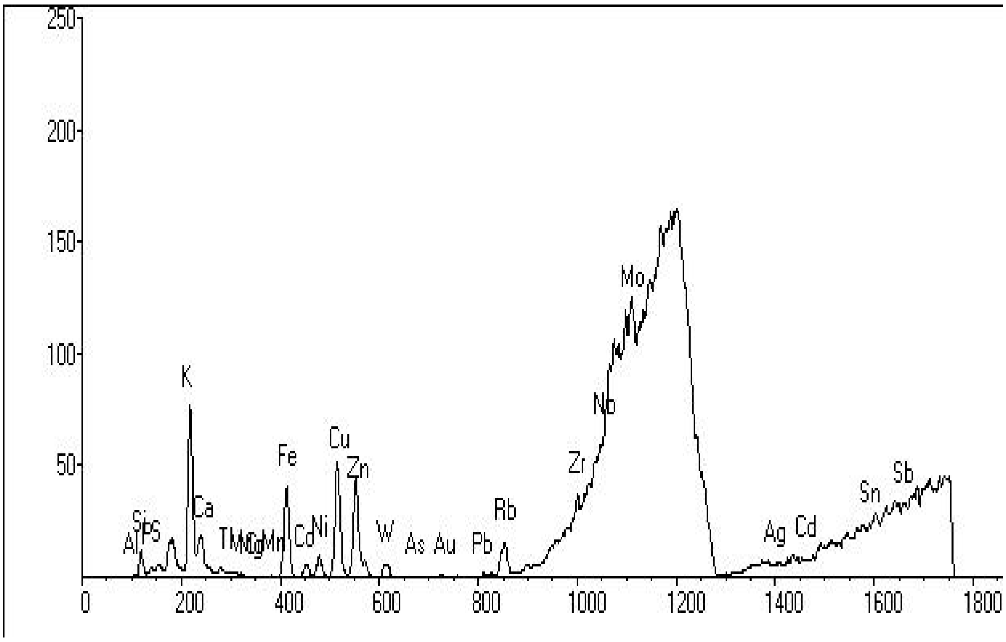

Fig 4.1 Heavy metals in Mango sample

The figure above shows the XRF graph of the heavy metals found in the mango sample collected. It displays the intensity and content of each of the heavy metals present. In this sample, the heavy metals present are magnesium (11.6691mg/kg), iron (1.1867mg/kg), antimony (5.9740mg/kg), and tin (6.6715mg/kg).

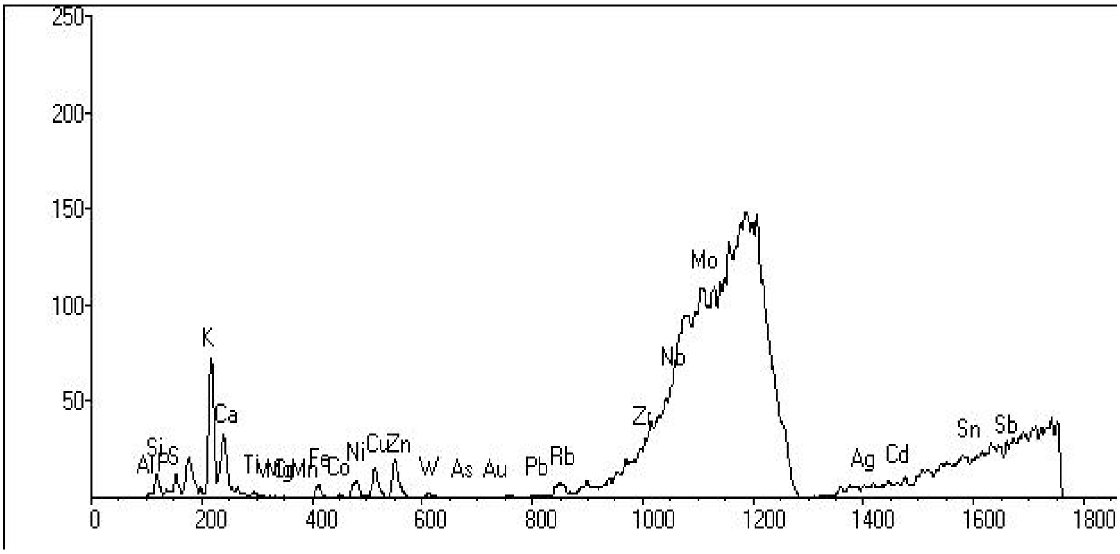

Fig 4.2 Heavy metals in Potato sample

The figure above shows the XRF graph of the heavy metals found in the potato sample collected. It displays the intensity and content of each of the heavy metals present. In this sample, the heavy metals present in significant quantities are tin (6.5668mg/kg). antimony (6.5668mg/kg).

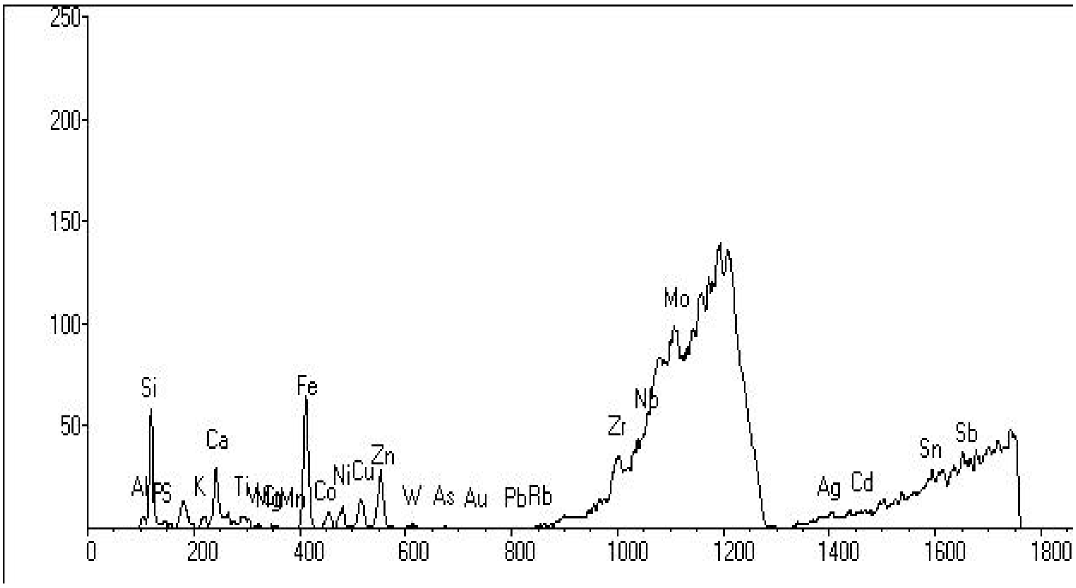

Fig 4.3 Heavy metals of sample location 1

The figure above shows the XRF graph of the heavy metals found in the soil sample collected from location 1. It displays the intensity and content of each of the heavy metals present. In this sample, the heavy metals present in significant quantities are tin (7.7611mg/kg), antimony (6.8697mg/kg), iron (2.0290mg/kg).

Table 4.1 Heavy metal concentrations of soil samples 1-3

Minerals (mg/kg)	**SL1**	**SL2**	**SL3**
Mg	**ND**	**20.0454**	**ND**
Al	**0.4572**	**0.5493**	**0.0853**
Si	**1.4553**	**1.8335**	**1.4680**
P	**0.0405**	**0.0199**	**0.0439**
S	**ND**	**0.0147**	**0.0238**
K	**0.0905**	**0.0501**	**0.0889**
Ca	**0.1495**	**0.1309**	**0.0650**
Ti	**0.2020**	**ND**	**ND**
V	**0.0079**	**0.0469**	**0.0302**
Cr	**0.0181**	**0.0027**	**ND**
Mn	**ND**	**0.0252**	**ND**
Co	**ND**	**0.0041**	**1.1641**
Fe	**2.0290**	**3.9001**	**0.2550**
Ni	**0.2205**	**0.2090**	**0.3463**
Cu	**0.3287**	**0.3232**	**0.2682ND**
Zn	**0.2728**	**0.2757**	**ND**
As	**ND**	**ND**	**ND**
Pb	**ND**	**0.0121**	**0.0031**
W	**0.2630**	**0.3477**	**0.2221**
Au	**ND**	**ND**	**ND**
Ag	**0.0513**	**ND**	**ND**
Rb	**0.0014**	**0.0016**	**ND**
Nb	**ND**	**ND**	**ND**
Mo	**0.1205**	**0.1384**	**0.0198**
Sb	**6.8697**	**6.4997**	**7.8970**
Cd	**0.0011**	**ND**	**ND**
Sn	**7.7611**	**6.8898**	**7.0168**

SL; Sample location

ND; Not detected

Table 4.2 Heavy metal concentrations of soil samples 4 - 6

MINERALS (mg/kg)	**SL4**	**SL5**	**SL6**
Mg	**ND**	**7.2851**	**ND**
Al	**0.1707**	**0.4852**	**0.0077**
Si	**0.8940**	**2.1042**	**1.4634**
P	**0.0343**	**0.0354**	**0.0350**
S	**0.0068**	**0.0015**	**0.0171**
K	**0.0204**	**0.0065**	**ND**
Ca	**0.0349**	**0.0510**	**0.0262**
Ti	**0.0992**	**ND**	**ND**
V	**0.0094**	**0.0101**	**0.0075**
Cr	**ND**	**ND**	**ND**
Mn	**ND**	**0.0141**	**ND**
Co	**0.0087**	**ND**	**0.0019**
Fe	**3.3519**	**1.2402**	**1.0473**
Ni	**0.1859**	**0.2886**	**0.2124**
Cu	**0.3457**	**0.3543**	**0.2882**
Zn	**0.2655**	**0.2614**	**0.2697**
As	**ND**	**ND**	**ND**
Pb	**0.0118**	**ND**	**0.0179**
W	**0.3796**	**0.2426**	**0.3772**
Au	**ND**	**ND**	**ND**
Ag	**0.0280**	**0.0257**	**0.0113**
Rb	**ND**	**ND**	**ND**
Nb	**ND**	**ND**	**0.0084**
Mo	**0.1254**	**0.1590**	**0.2321**
Sb	**6.7579**	**6.0565**	**6.8895**
Cd	**ND**	**ND**	**0.0011**
Sn	**7.9348**	**6.7679**	**7.9415**

SL; Sample location

ND; Not detected

Table 4.3 Heavy metal concentrations of soil samples 7 - 9

MINERALS (mg/kg)	**SL7**	**SL8**	**SL9**
Mg	**7.0614**	**ND**	**ND**
Al	**0.5754**	**0.2622**	**0.3258**
Si	**2.0259**	**0.8112**	**2.3455**
P	**0.0438**	**0.0256**	**0.0167**
S	**ND**	**0.0164**	**ND**
K	**0.0225**	**ND**	**0.0479**
Ca	**0.0665**	**0.0349**	**0.0338**
Ti	**ND**	**0.2019**	**ND**
V	**0.0186**	**ND**	**0.0084**
Cr	**ND**	**ND**	**0.0203**
Mn	**0.0236**	**0.0238**	**ND**
Co	**ND**	**0.0057**	**ND**
Fe	**2.6657**	**4.3457**	**1.3654**
Ni	**0.2245**	**0.2327**	**0.2447**
Cu	**0.2838**	**0.3408**	**0.2699**
Zn	**0.2752**	**0.2681**	**0.2695**
As	**ND**	**ND**	**ND**
Pb	**ND**	**ND**	**0.0185**
W	**0.2453**	**0.2943**	**0.2543**
Au	**0.0978**	**0.0210**	**ND**
Ag	**ND**	**0.0220**	**ND**
Rb	**0.0013**	**ND**	**ND**
Nb	**ND**	**ND**	**ND**
Mo	**0.2316**	**0.1598**	**0.1488**
Sb	**6.9219**	**6.7201**	**7.1278**
Cd	**ND**	**ND**	**ND**
Sn	**7.3469**	**6.8317**	**7.7893**

SL; Sample location

ND; Not detected

Table 4.4 Heavy metals of vegetable samples

Mineral(mg/kg)	**A**	**B**	**C**	**D**
Mg	**11.6691**	**ND**	**6.4924**	**ND**
Al	**0.0230**	**0.1585**	**0.1217**	**0.0765**
Si	**0.1635**	**0.2308**	**0.1548**	**0.2302**
P	**0.0469**	**0.0510**	**0.0790**	**0.0725**
S	**0.1246**	**0.2675**	**0.2075**	**0.2098**
K	**1.2657**	**1.2793**	**0.7134**	**0.8793**
Ca	**0.0471**	**0.1440**	**0.4576**	**0.2615**
Ti	**ND**	**ND**	**ND**	**ND**
V	**0.0128**	**ND**	**0.0343**	**ND**
Cr	**ND**	**ND**	**ND**	**ND**
Mn	**ND**	**ND**	**ND**	**ND**
Co	**ND**	**ND**	**ND**	**ND**
Fe	**1.1867**	**0.2800**	**0.3475**	**0.2726**
Ni	**0.1479**	**0.2111**	**0.1696**	**0.1680**
Cu	**1.0633**	**0.3905**	**0.3818**	**0.2912**
Zn	**0.2880**	**0.2347**	**0.2521**	**0.2233**
As	**ND**	**ND**	**ND**	**ND**
Pb	**ND**	**0.0096**	**0.0126**	**ND**
W	**0.7978**	**0.2982**	**0.2209**	**0.2631**
Au	**0.0993**	**ND**	**ND**	**ND**
Ag	**ND**	**ND**	**0.0062**	**0.0137**
Rb	**0.0404**	**0.0190**	**0.0079**	**0.0120**
Nb	**ND**	**ND**	**ND**	**ND**
Mo	**0.1213**	**0.0741**	**0.1448**	**0.2208**
Cd	**ND**	**0.0016**	**ND**	**ND**
Sn	**6.6715**	**6.5668**	**6.8326**	**6.9276**
Sb	**5.9740**	**5.6982**	**5.8420**	**6.0364**

ND; Not detected

A; Mango *(Mangifera indica)*

B; Potato *(Ipomoea batatas)*

C; Orange *(Citrus sinensis)*

D; Bitter leaf **(***Vernonia amygdalina)*

4.2 TRANSFER FACTOR

The ratio of the concentrations of heavy metals in vegetables to their respective concentrations in soil is known as the transfer factor, or bio-concentration factor, or bioaccumulation factor Tasrina et al. (2015); Zhou et al. (2016); Ramteke et al. (2016); Rehman et al. (2017), It is an important tool for accessing and explaining the migration of soil HMs to plants and its availability to humans through the food chain Tasrina et al. (2015). It is controlled by the nature of plants and soils. Tasrina et al. (2015).

The transfer factors of the heavy metals discovered are shown in table 4.3. The transfer factor in location 1,2,4,6 and 9 were less than one (1). However, in location 3, the transfer factor of iron is greater than one (1). In location5, the transfer factor of magnesium was 1.60 in mango, Sn was 1.01 in orange, and 1.02 in bitter leaf. In location 7, the transfer factor of magnesium was 1.05 in mango. In location 8, the transfer factor of Sn was 1.00 in both orange and bitter leaf.

High TF is an indication that the plants has high ability to take up soil metals or the soil has low capability to hold back metal Tasrina et al. (2015). The TFs are in the other of Cd > Pb > Zn. Atikpo et al. (2021) in his research, observed mean metals TFs order of Pb > Cd > Cr > Zn for some vegetables studied at Agbabu farm settlement in settlement in western Nigeria.

Table 4.5 transfer factors of Cd, Pb and Zn from soil to vegetables

	SL1	SL2	SL3	SL4	SL5	SL6	SL7	SL8	SL9
Cd									
Mango	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**
Potato	**1.45**	**ND**	**ND**	**ND**	**ND**	**ND**	**1.45**	**ND**	**ND**
Orange	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**
Bitter leaf	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**
Pb									
Mango	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**
Potato	**ND**	**0.79**	**3.10**	**0.81**	**ND**	**0.54**	**ND**	**ND**	**0.52**
Orange	**ND**	**1.04**	**4.06**	**1.07**	**ND**	**0.70**	**ND**	**ND**	**0.68**
Bitter leaf	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**
Zn									
Mango	**1.06**	**1.04**	**ND**	**1.08**	**1.10**	**1.07**	**1.05**	**1.07**	**1.07**
Potato	**0.86**	**0.85**	**ND**	**0.88**	**0.90**	**0.87**	**0.85**	**0.88**	**0.87**
Orange	**0.92**	**0.91**	**ND**	**0.95**	**0.96**	**0.93**	**0.92**	**0.96**	**0.94**
Bitter leaf	**0.82**	**0.81**	**ND**	**0.84**	**0.85**	**0.83**	**0.81**	**0.83**	**O.83**

Table 4.6 Transfer factors of Sb, Sn and Fe from soil to vegetables

	SL1	SL2	SL3	SL4	SL5	SL6	SL7	SL8	SL9
Sb									
Mango	**0.8696**	**0.9191**	**0.7565**	**0.8840**	**0.9864**	**0.8671**	**0.8631**	**0.8890**	**0.8381**
Potato	**0.8295**	**0.8767**	**0.7216**	**0.8432**	**0.9408**	**0.8271**	**0.8232**	**0.8479**	**0.7994**
Orange	**0.8504**	**0.8988**	**0.7398**	**0.8645**	**0.9646**	**0.8480**	**0.8440**	**0.8693**	**0.8196**
Bitter leaf	**0.8787**	**0.9287**	**0.7644**	**0.8932**	**0.9967**	**0.8762**	**0.8721**	**0.8983**	**0.8469**
Sn									
Mango	**0.8596**	**0.9683**	**0.9508**	**0.8408**	**0.9858**	**0.8401**	**0.9081**	**0.9766**	**0.8565**
Potato	**0.8295**	**0.8767**	**0.7216**	**0.8432**	**0.9408**	**0.8271**	**0.8232**	**0.8479**	**0.7994**
Orange	**0.8504**	**0.8988**	**0.7398**	**0.8645**	**0.9646**	**0.8480**	**0.8440**	**0.8693**	**0.8196**
Bitter leaf	**0.8787**	**0.9287**	**0.7644**	**0.8932**	**0.9967**	**0.8762**	**0.8721**	**0.8983**	**0.8469**
Fe									
Mango	**0.5849**	**0.3043**	**4.6537**	**0.3540**	**0.9569**	**1.1331**	**0.4452**	**0.2731**	**0.8691**
Potato	**0.1380**	**0.0718**	**1.0980**	**0.0835**	**0.2258**	**0.2674**	**0.1050**	**0.0644**	**0.2051**
Orange	**0.1712**	**0.0891**	**1.3627**	**0.1037**	**0.2802**	**0.3318**	**0.1304**	**0.0800**	**0.2545**
Bitter leaf	**0.1344**	**0.0699**	**1.0690**	**0.0813**	**0.2198**	**0.2603**	**0.1023**	**0.0627**	**0.1996**

SL= Sample location

Transfer factor = $\frac{Heavy\ metal\ concentrations\ of\ plants}{Heavy\ metal\ concentration\ of\ soil}$

4.3 COMPARISON OF RESULT WITH STANDARD VALUES

4.3.1 HEAVY METAL CONCENTRATIONS

The concentrations (mg/kg) of heavy metals in both soil and vegetable samples are shown in table 4.1-4.3. However, cadmium (Cd), gold (Au), arsenic (As) and niobium (Nb) were not detected in the soil samples, while chromium (Cr), manganese (Mn), cobalt (Co), arsenic (As) and niobium (Nb) were not detected in the vegetable samples. Generally, the concentrations of the heavy metals in the soil samples are in the decreasing order: Mg>Sn>Sb>Fe>Si>K. The trend is also similar for the vegetable samples.

4.3.1.1 IRON (Fe)

All plants and animals require iron as it is the most prevalent and essential element. However, in excessive concentrations, it can harm human tissues and result in a number of diseases. The concentrations of iron in the soil sample range from 0.2550 to 3.9001mg/kg and from 0.2726 to 1.1867 in the vegetable samples (Table 4.1 to 4.2). The variations in the absorption of iron from the soil by the plants tissues are clearly seen in the low iron contents in the vegetable samples. The high concentrations of iron in the soil samples may indicate a very rich anthropogenic source of iron that allows the percolation of iron to the soil depths rather the surfaces. The low concentrations of iron in the vegetable samples compared to its abundant availability in the soil, can be attributed to: (i) possible leaching of iron from the soil surface and runoff during rainfall, (ii)) low absorption of iron by the tissues of the vegetable samples.

Iron is necessary for the synthesis of chlorophyll and the activation of some respiratory enzymes. Iron deficiency in plants results in chronic chlorosis of its leaves. A high level of exposure to iron dust may lead to respiratory diseases such as chronic bronchitis and difficulties in breathing.

The iron contents of the vegetable samples and the soils on which they grow are less than the FAO/WHO (2001) safe limit of 425.00 mg/kg.

4.3.1.2. TIN (Sn)

Tin in its single state is not very toxic. However, in its organic form, it is very toxic. In this form, tin can stay in the environment for long, as it is not biodegradable. They disturb growth, reproduction and some enzyme process.

Tin oxide is insoluble and the ore resists weathering strongly. Hence, the amount of tin found in soils and vegetables is generally between 1-4ppm (*Heavy Metals - Lenntech*, n.d.). Tin is used for coating steel containers, food preservation, superconducting magnets, e.t.c

Some acute effects of tin include urinary problems, breathlessness, stomach aches, eye and skin irritation, chromosomal damage, liver damage, shortage of red blood cells, brain damage.

The tin contents of the vegetable samples and the soils on which they grow ranged from 5.6982 to 7.8970 mg/kg and is less than the WHO recommended permissible limit of 38mg/kg. The concentrations of tin in the soil samples indicate a high source that allows its percolation into the depths of the soil. The source of this tin concentration could be linked to the metals on the coffin.

4.3.1.3 ANTIMONY (Sb)

Antimony is not an essential element for plants, humans and animals. Some plants can accumulate antimony in relatively high amounts in edible plant parts or medicinal herbs such that it constitutes health risks to animals and humans. Antimony is introduced into soil and then taken up by plants from different sources such as leaching of mining wastes, weathering of sulfide ores and anthropogenic activities. The absorption of antimony from the soil by the plant tissues are clearly seen in the antimony contents of the vegetable samples. The high concentrations of antimony in the soil samples may indicate a rich source of antimony that allows its percolation into the soil depths rather the surfaces. This source most likely came from the paints sprayed on the coffins in the cemetery.

Consumption of food contaminated with antimony can cause cancer, liver and cardiovascular diseases.

The antimony contents of the vegetable samples and the soils on which they grow (6.5668 to 7.9415) are less than the WHO safe limit of 36 mg/kg.

4.3.1.4 MAGNESIUM (Mg)

Magnesium is an essential element for plants. It aids in the building up of chlorophyll and thus, it is important for photosynthesis.

A high intake of magnesium as a result of consumption of vegetables with high concentrations could lead cardiac arrest, nausea and vomiting, difficulty in breathing, fatigue, e.t.c

Magnesium was only detected in soil sample 2 (20.045mg/kg), 5 (7.2851mg/kg) and 7(7.0614mg/kg), and undetected in the rest soil samples. In the vegetable samples, magnesium was only detected in mango (11.6691mg/kg) and orange (6.4924mg/kg) and undetected in potato and bitter leaf. These concentrations are less than the WHO permissible limit of 100mg/kg.

4.3.1.5 CADMIUM (Cd)

Cadmium was only detected in soil sample 1 (0.0011mg/kg) and 6 (0.0011mg/kg), while undetected in the rest soil samples. In the vegetable samples, cadmium was only detected in potato, (0.0016mg/kg). These concentrations are below the WHO permissible limit of 0.02mg/kg.

Excessive intake of cadmium could reduce plant growth. In humans, consumption of vegetables containing cadmium could lead to various kinds of cancer, such as pancreatic cancer, kidney, breast and lung cancer, e.t.c .

4.3.1.6 SILICON (Si)

Silicon is of great benefits to soil and protects plants from diseases and environmental stresses by improving plants defenses against diseases. However, it is not an essential metal. Silicon was detected in all of the soil samples, with values ranging from 0.8112mg/kg to 2.1042mg/kg. in the vegetable samples, the silicon concentration range from 0.1548 to 0.2308mg/kg. These values are less than the WHO recommended permissible limit of 122mg/kg,

4.4 HEALTH RISK ASSESSMENT OF HEAVY METALS DETECTED

The health risks associated with the consumption of heavy metals through the consumption of vegetables were analyzed by assessing the daily metal intake (DIM), health risk index (HRI), target health quotient (THQ), and the total target health quotient (TTHQ) parameters. DIM was computed using equation 2 (Khan et al., 2010), HRI was computed using equation 3, THQ was computed using equation 4, and TTHQ was computed using equation 5, as explained in chapter 3.

Table 4.7 DIM computation for HM

Metals	Adults	Children
Zn	0.07	0.18
Pb	0.003	0.008
Cd	0.0003	0.0007
Sb	1.5026	3.8482
Sn	1.7245	4.4163
Fe	0.2954	0.7565

Table 4.8 HRI computation for HM

Metals	Adults	Children
Zn	20	51.43
Pb	0.87	2.29
Cd	0.09	2.0
Sb	3756.5	9620.5
Sn	574.83	14721
Fe	0.422	1.08

Table 4.9 THQ and TTHQ computation

Metals	Adults	Children
Zn	0.007	0.03
Pb	0.59	2.74
Cd	2.05	9.59
Sb	7.045	18.49
Sn	9.39	24.66
Fe	0.004	0.01
	$\sum THQ =$ 19.086	$\sum THQ =$ 55.52
	TTHQ = $\sum THQ$ (Adult + Children) = 74.606mg/kg	

4.5 HEALTH RISK ASSESSMENT OF THE SAMPLE LOCATION

There is not much farming activities in the second cemetery area. Most of the farming activities are on a small scale for personal consumption. The parameters (DIM, HRI and THQ) for assessment of health risk caused by the ingestion of contaminated crops from the area of study were determined for adults and children. The concentration of a metal's toxicity is usually a function of daily intake of the metal (DIM) (Edogbo et al. 2020).

The daily intake values of Sb and Sn through ingestion of these vegetables were found to be higher than the recommended oral reference doses (RfDs) of 0.0004mg/kg/day and 0.0003mg/kg/day respectively, while that of iron was lower than the (RfDs) for adult, but higher than the dose for children.

The daily intake values of Pb and Zn through ingestion of the vegetables were found to be higher than the oral reference doses (RfDs) of 0.0035mg/kg/day and 0.300 mg/kg/day respectively. The respective THQ Cd intake of 2.05 and 9.59 mg/kg/day by adults and children was recorded from the ingestion of mango, potato, orange and bitter leaf. The DIM values of Cd for children and adults were higher than the ones reported by (Atikpo & Owamah 2022) for vegetables studied in Amaonye forest farmland, Eastern Nigeria.; (Pan et al. 2016) in Zhejiang, China; and (Rehman et al. 2017) in five regions of Pakistan. The minimum and maximum values of daily intake of Cd were lower than the RfD (0.001 mg/kg/day) and implies no negative health consequences from perennial consumption of the Cd contaminated vegetables. (Yang et al. 2016) reported that the ingestion of leafy vegetable is an important route to human exposure to Cd in many parts of the word

The THQ values obtained for children were all higher than the ones obtained for adults. The THQ of Pb for adults was 0.59mg/kg, while that of children was 2.74mg/kg. Higher THQ values for children than for adults were also reported by (Zhou et al. 2016) and (Edogbo et al. 2020). This is attributable to variations in body weight and daily vegetable intake between children and adults (Zhou et al. 2016).

Relative to the respective maximum HRI values for Zn, Edogbo et al. (2020) obtained higher values of HRI for tomato ingested by children but lower values of HRI for the other vegetables ingested by children and adults in Challawa, Kano, in Nigeria. Ramteke et al. (2016) obtained higher HRI values of Zn for selected vegetables in India than the ones in this study. This could be due to differences in average body weights and differences in DIMs (Ramteke et al. 2016; Zhou et al. 2016; Rehman et al. 2017; Edogbo et al. 2020).

The study revealed that the health risks parameters (THQ) values for the metals were in decreasing order of Sn>Sb>Fe>Cd>Pb>Zn showing that Sn is the severest pollutant. HRI values for the metals were in decreasing order of Sn>Sb>Fe>Zn>Pb>Cd. Zhou et al. (2016) also reported that the THQs of Zn ingestion were less than one, showing no potential health risks in connection with Zn ingestion through vegetables, but the TTHQ was more than one, showing potential health risk.

4.6 CONCENTRATION OF VEGETABLES

Sn, Sb, Fe, Pb and Cd contamination renders vegetables from these locations unfit for human consumption. Consuming these vegetables in diets could have negative health effects. Adimalla and Wang (2018). Also, planting on these soils should be discouraged. Rc et al. (2015) in his research reported that vegetables vary in their ability to take up metals from soils with their species. Ramteke et al. (2016) also discovered this for different species of vegetables studied in India; Rehman et al. (2017) for Pb and Cd in different species studied in some selected regions of Pakistan; and Edogbo et al. (2020) for different species studied in Challawa, Kano in Nigeria. The high concentration of magnesium could be as a result of the decomposition of corpses, which turn into nutrients in the soil, as magnesium is an essential nutrient in the human body.

CHAPTER FIVE

5.0 RECOMMENDATIONS AND CONCLUSIONS

5.1 CONCLUSIONS

The study has revealed that the cemetery soils are polluted with Sn, Sb, Fe. Pb, Cd and Zn as concentrations obtained were, higher than their respective WHO standards set for soils used for crop production. Thus, the vegetable samples *Vernonia amygdalina, Ipomoea batatas, Citrus sinensis, and Magnifera indica* planted on the soils are polluted and not fit for consumption.

The results obtained showed that the soil was polluted with Sn, Sb, Fe Pb, Cd and Zn. The concentration of Sn, Sb, and Fe were lower than the maximum allowable limit (200mg/kg, 36mg/kg, 20mg/kg) respectively, and Zn was higher than the maximum allowable limit (0.3 mg/kg) respectively set for soils used for crop production. The concentration of Pb and Cd were lower than the maximum allowable limits (0.1mg/kg, 0.3mg/kg).

The daily intake values of Sb and Sn of these vegetables were found to be higher than the recommended oral reference doses (RfDs) of 0.0004mg/kg/day and 0.0003mg/kg/day respectively, while that of iron was lower than the RfDs for adult, but higher than the dose for children. Daily intakes of Cd and Zn were lower than the respective oral reference doses of 0.001 and 0.300 mg/kg/day, while that of Pb was higher than the oral reference dose of 0.0035mg/kg/day. The health risk index and target health quotient values were, respectively, greater than one, indicating that the ingestion of the vegetables might affect human health negatively. The transfer factor for Cd was highest in *Ipomoea batatas*, Pb was highest in *Citrus sinensis* and Zn was highest in *Magnifera indica*.

The respective values of THQ for Sn, Sb, Fe, Pb, and Cd in the respective vegetables were above one, while the value of Zn was less than one.

However, the values of TTHQ for all the studied metals in the vegetables were greater than one. The vegetables studied were not fit for diet because of the high health risks associated with their ingestion. Children consuming vegetables from these locations in the study area were seen to be in greater danger of health risks than the adults.

5.2 RECOMMENDATIONS

Based on the results obtained from this study, the following recommendations are given;

1. The residents of the study location should avoid planting on the soils.
2. Vegetables planted on these soils should not be eaten.
3. Other methods of analysis of metals in soil and vegetable should be adopted for the same soil and vegetable samples.
4. Soil remediation processes such as the following should be employed to reduce the concentration of these metals in the soil samples;
    I. Phyto-remediation: This is the use of certain plants called hyper-accumulators to extract, reduce or stabilize heavy metals in the soil. They absorb and concentrate metals present from the soil. They include willow trees used to extract cadmium and sunflowers used to extract lead.
    II. Chemical stabilization: This is the use of chemicals such as phosphate, lime or organic matter to stabilize and reduce heavy metals present in soil.
    III. Bio-remediation: This is the use of microorganisms such as bacteria or fungi to convert heavy metals into less toxic ones.

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APPENDIX

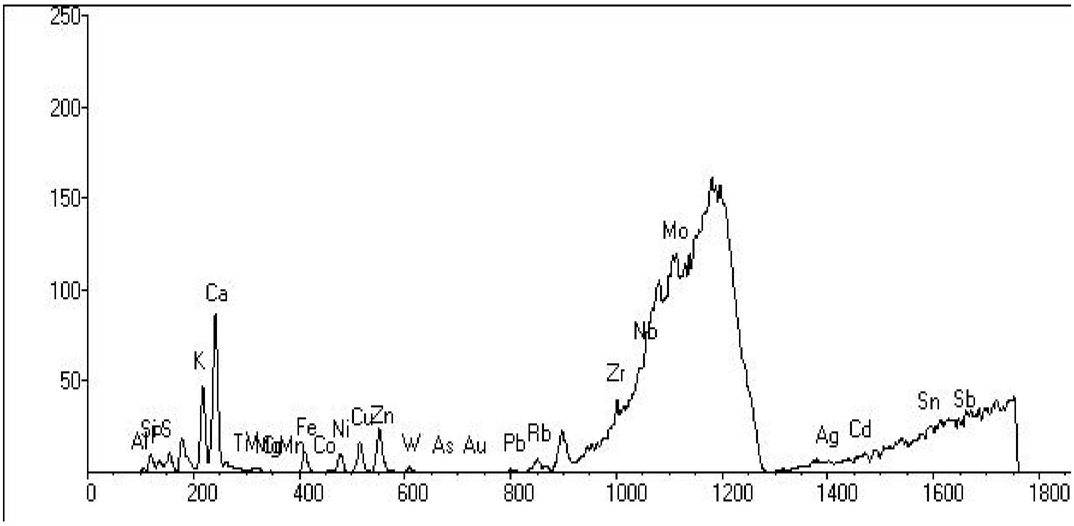

Fig 4.1 Heavy metals in Orange sample

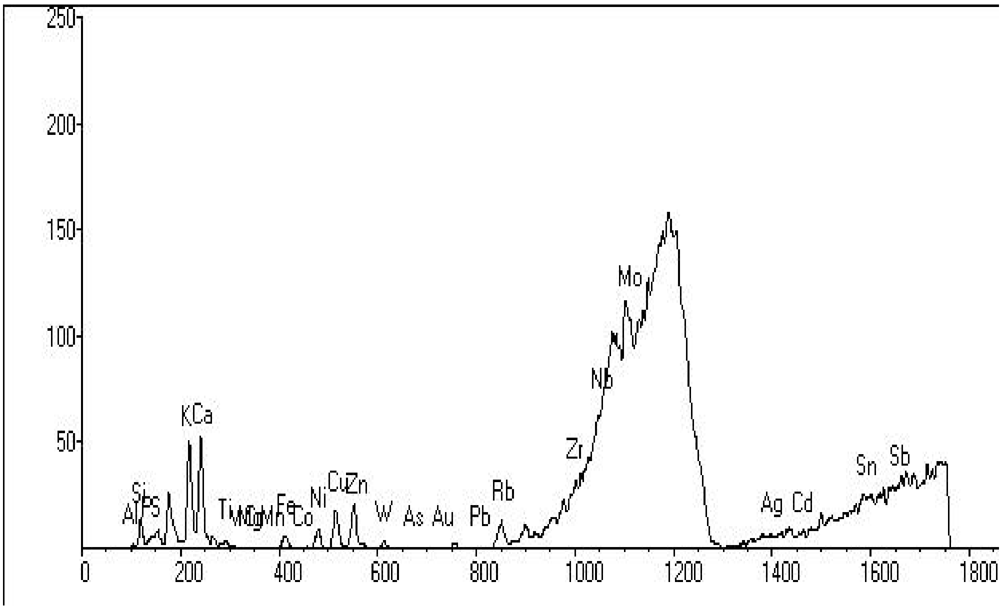

Fig 4.2 Heavy metals of Bitter leaf

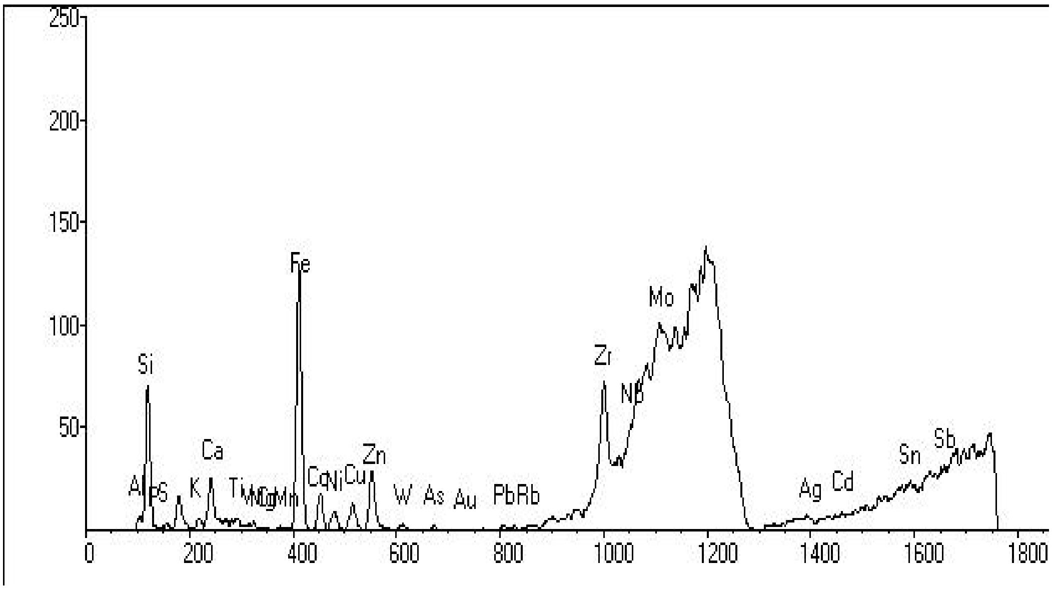

Fig 4.3 Heavy metals of soil sample location 2

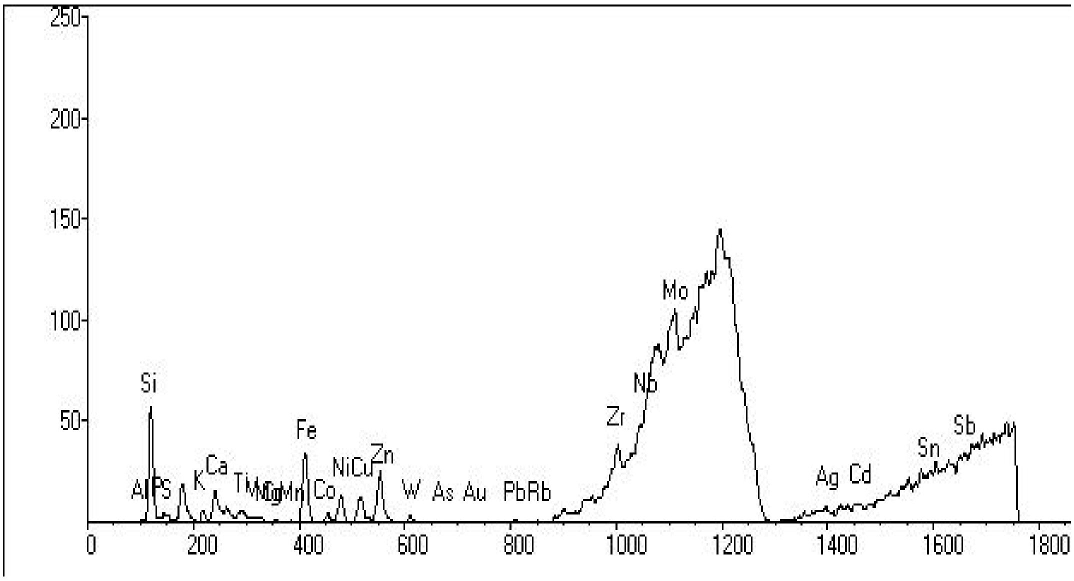

Fig 4.4 Heavy metals of soil sample location 3

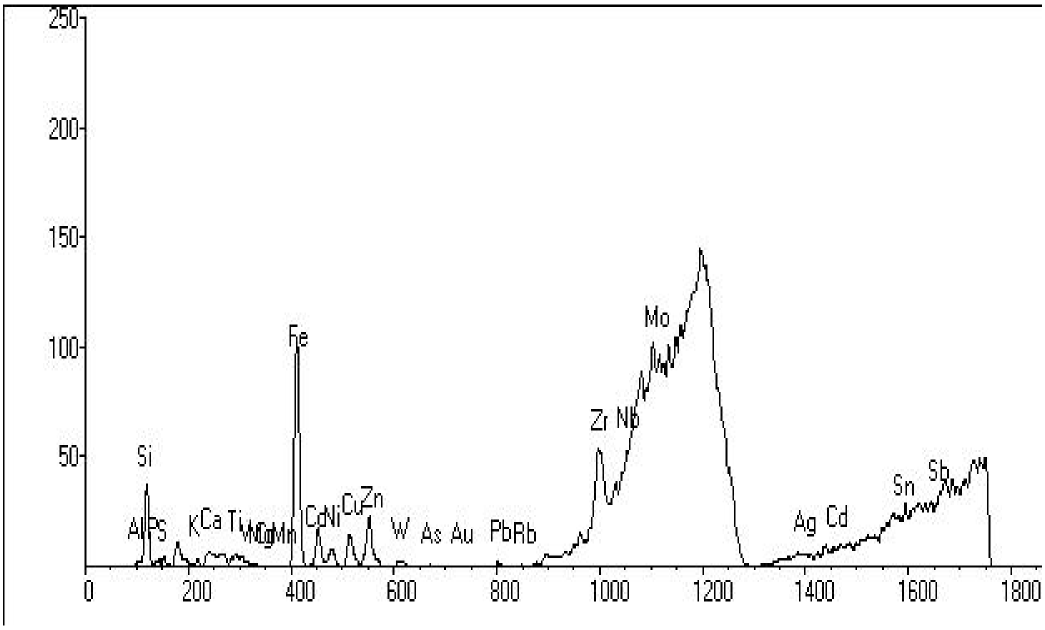

Fig 4.5 Heavy metals of soil sample location 4

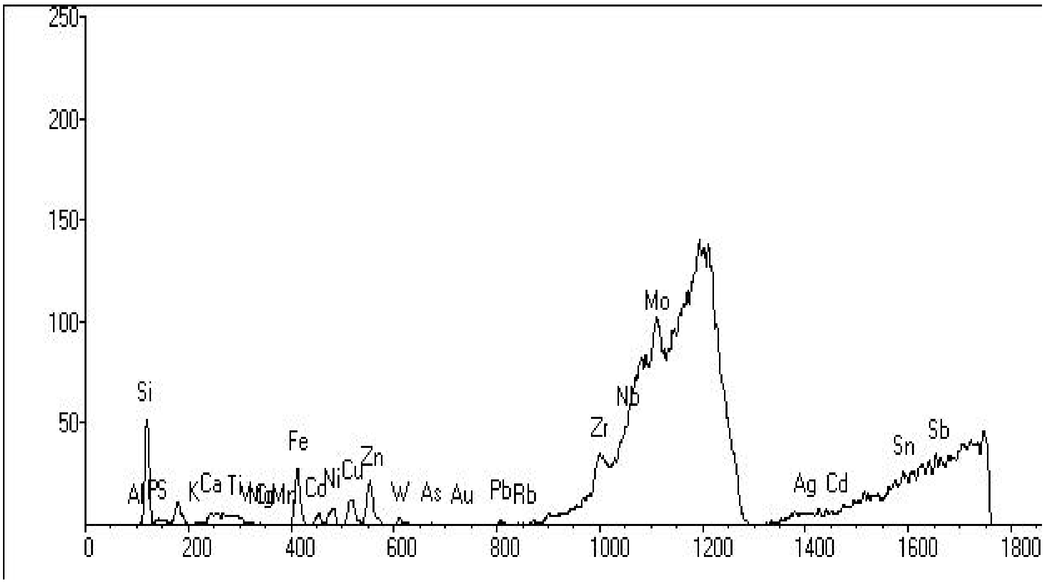

Fig 4.6 Heavy metals of soil sample location 5

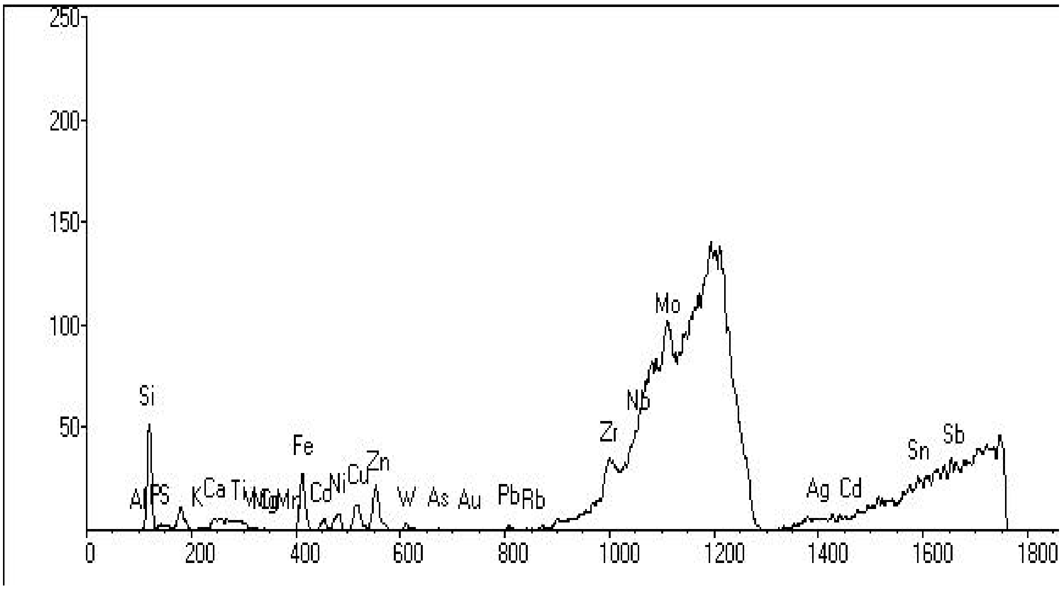

Fig 4.7 Heavy metals of soil sample location 6

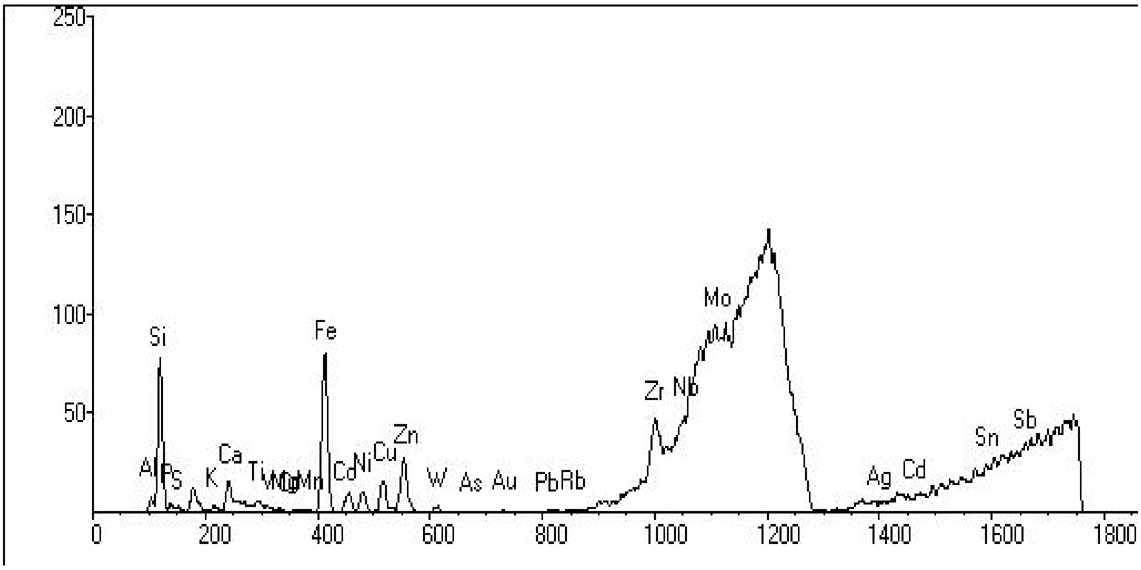

Fig 4.8 Heavy metals of soil sample 7

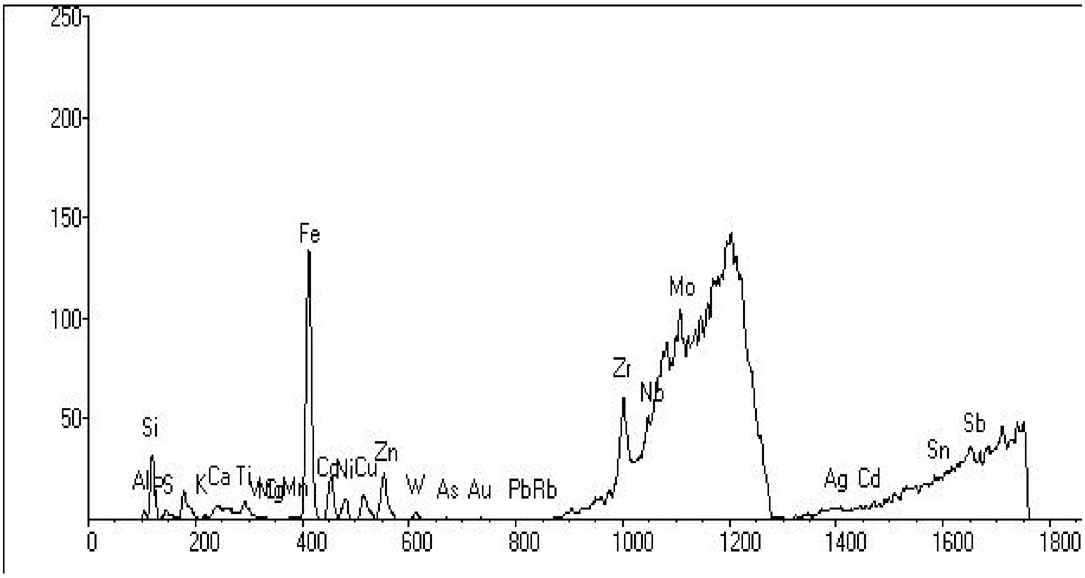

Fig 4.9 Heavy metals of soil sample 8

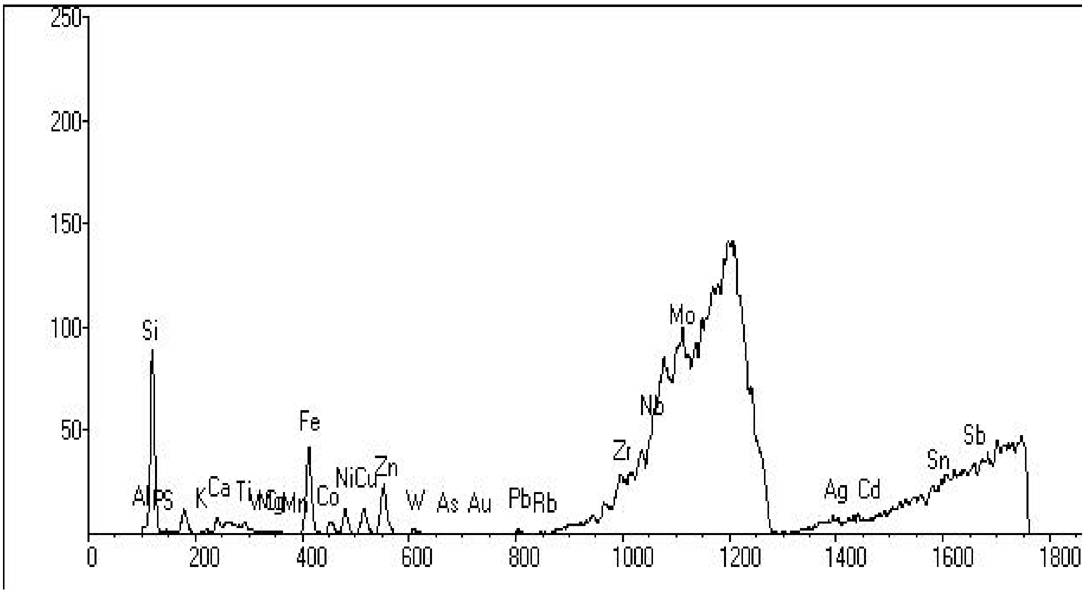

Fig 4.10 Heavy metals of soil sample 9

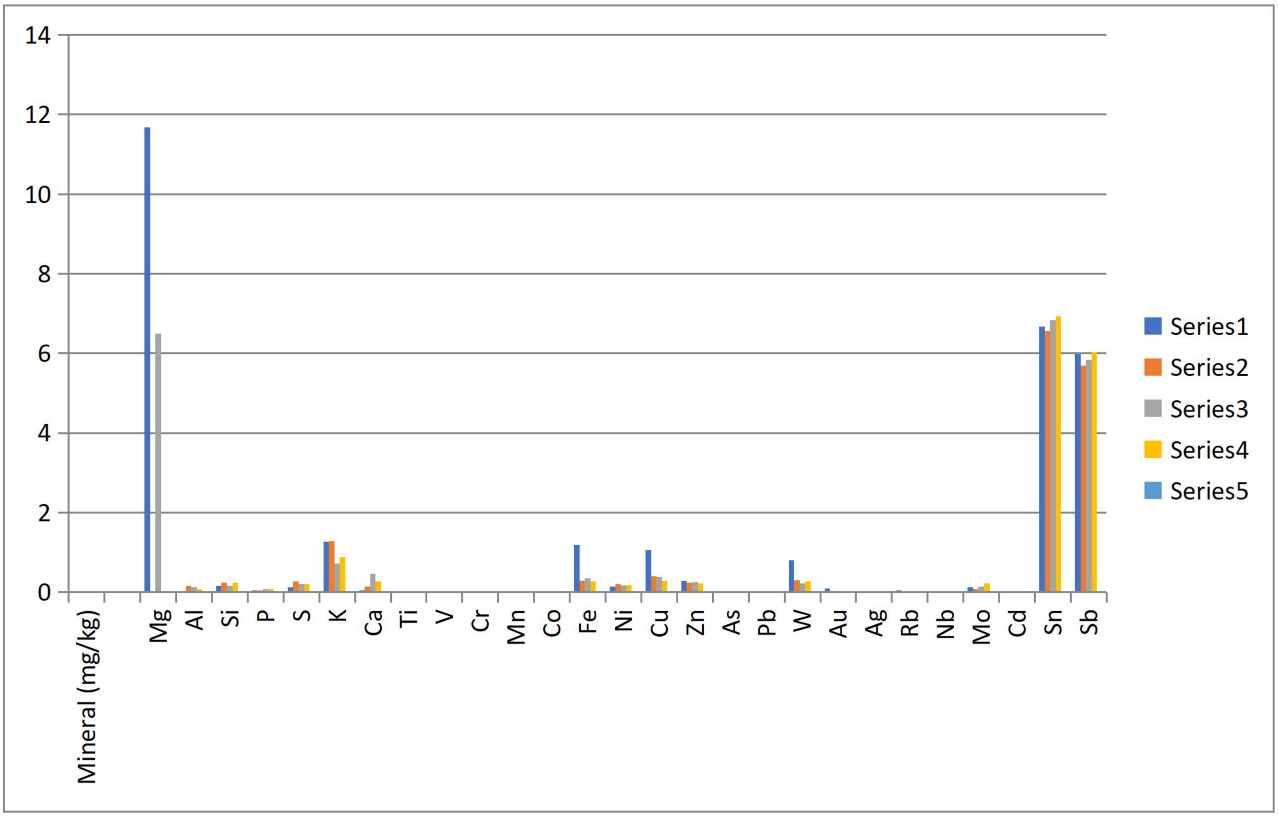

Fig 4.11 Bioavailability of heavy metals in the vegetable samples

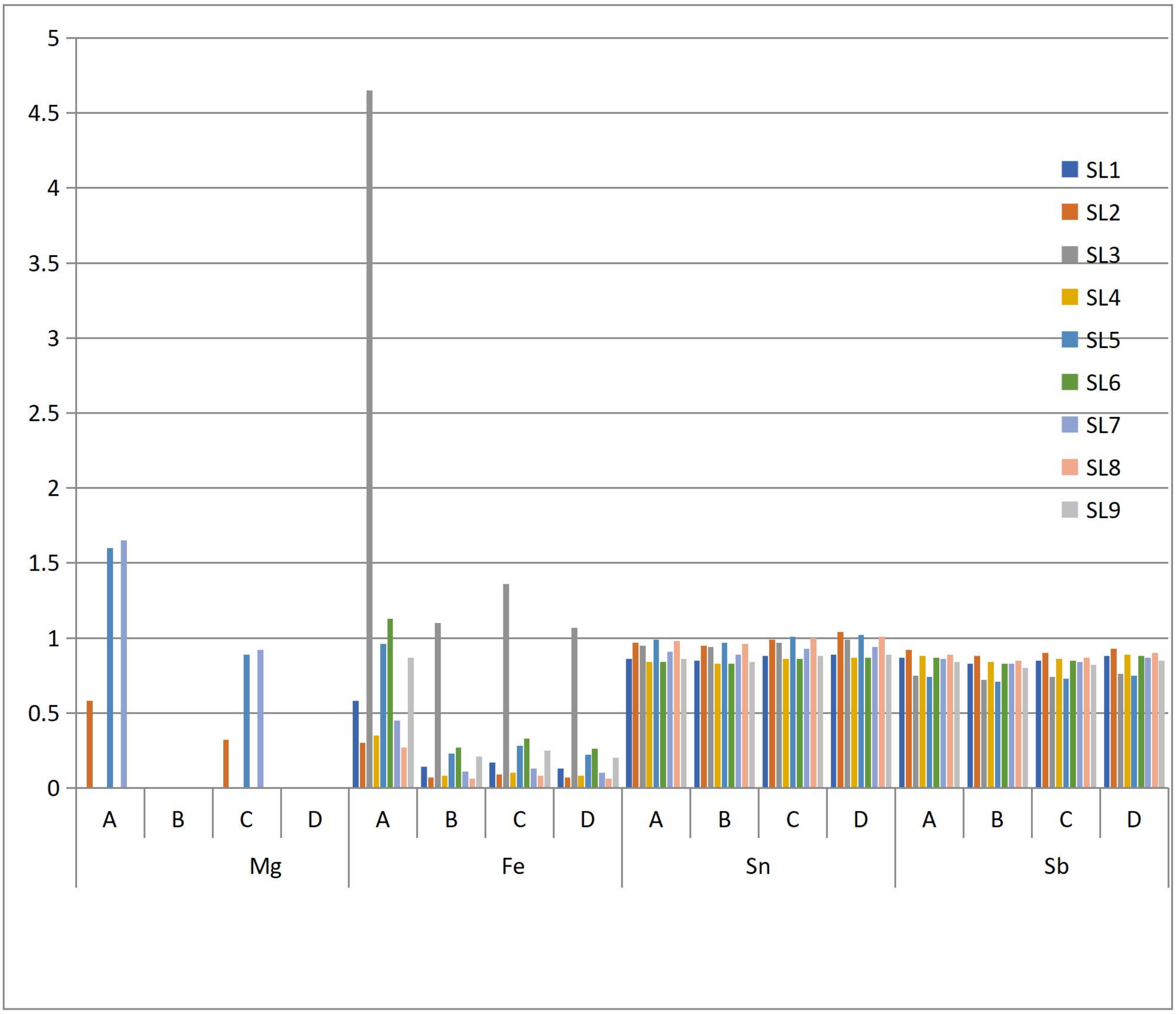

Fig 4.12 Transfer factor of HM from soil to vegetables