HEAVY METALS CONCENTRATION OF CELOSIA (*CELOSIA ARGENTAE*) RAISED ON DUMPSITE SOILS IN BENIN CITY

BY

Josephine IGUODALA (Miss)

AGRI600600

DEPARTMENT OF SOIL SCIENCE AND LAND MANAGEMENT

FACULTY OF AGRICULTURE

UNIVERSITY OF BENIN

BENIN CITY

OCTOBER, 2023.

HEAVY METALS CONCENTRATION OF CELOSIA (*CELOSIA ARGENTAE*) RAISED ON DUMPSITE SOILS IN BENIN CITY

BY

Josephine IGUODALA (miss)

AGRI600600

A PROJECT REPORT SUBMITTED TO THE

DEPARTMENT OF SOIL SCIENCE AND LAND MANAGEMENT,

FACULTY OF AGRICULTURE, UNIVERSITY OF BENIN, BENIN CITY

IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR OF AGRICULTURE DEGREE B. AGRIC (SOIL SCIENCE AND LAND MANAGEMENT

OCTOBER, 2023.

CERTIFICATION

This is to certify that this research project **"Heavy metals concentration of celosia (*celosia argentae*) raised on dumpsite soils in Benin City"** was carried out by **Josephine IGUODALA (miss)** of the Department of Soil Science and Land Management, Faculty of Agriculture, University of Benin City, Edo State, Nigeria.

____________________________ __________________

Prof. J.U. Chokor **Date**
(Project Supervisor)

____________________________ __________________

Dr. (Mrs) A.O. Bakare **Date**
Head of Department

DEDICATION

This project is dedicated to God Almighty and my beloved parents may God continue to bless and protect them

ACKNOWLEDGEMENT

Wholeheartedly, I wish to express my gratitude to the most excellent and omnipotent God for his infinite mercies and protection

My appreciation goes to my supervisor, Prof. J.U. Chokor whose assistance went a long way in contributing to the success of this project work, I say a big thank you sir. And to Mr Edmond my course adviser for his advice, correction and time he created for me during my course of study. I appreciate you. And to the Head of Department (H.O.D), Dr Mrs A.O Bakare, the Dean of the Faculty of Agriculture, Prof. E. R. Orhue and to other lecturers Prof. A. I. Ogboghodo, Prof. J. Ogeh, Prof. Prof. Ehigiator, Dr. IK, Mr. Mike, and others for their academic impact in my life. I appreciate you all.

My profound gratitude goes to my beloved parents, Mr and Mrs Enorense Iguodala for their parental care and love, financial, moral and academic right from birth till date, May God reward you both. Amen

Special thanks goes to my siblings, Mrs Osasere William, Mrs Oduwa, Ezewele, Mrs blessing Evbomwan, Faith, Doris, Destiny and Raymond for their prayers and love.

And to my course mates Valerie, Bridget and mama twins to mention a few I sincerely appreciate all that advice and encouragement you gave to me throughout my schooling days. I pray that God grant your heart desires. Amen

TABLE OF CONTENT

CHAPTER TWO: LITERATURE REVIEW

CHAPTER THREE: MATERIALS AND METHODS

CHAPTER FOUR: RESULT AND DISCUSSION

CHAPTER FIVE

LIST OF TABLES

ABSTRACT

This study was conducted in the Greenhouse of the Department of Soil Science and Land Management, Faculty of Agriculture, University of Benin, Benin City, to determine the heavy metal concentration of *Celosia argentae* raised on soils from dumpsites in Benin City, Edo State. Soil samples were collected from dumpsites from three different land uses around Ugbowo Campus of University of Benin City. The soils from the dumpsites were filled into plastic buckets and used to raise *Celosia argentae*. The experiment was laid out in a Completely Randomized Design (CRD) with three treatments and replicated three times. Soil and plant sample were collected and taken to the laboratory for analysis and standard procedures were used to analyze the samples. Data obtained were subjected to analysis of variance (ANOVA) and Duncan's New Multiple Range Test was used to separate the means at 5% level of significance.

The parameters measured include: pH, Total organic carbon, Total nitrogen, Available phosphorus, Sand, Silt, Clay, Boron, Chlorine, Copper, Iron, Manganese, Molybdenum, Zinc, Lead, Chromium and Cadmium for the dumpsite soils, while the micro nutrients (Boron, Chlorine, Copper, Iron, Manganese, Molybdenum, Zinc) and heavy metals (Lead, Chromium and Cadmium) for the plant samples. The results show that the pH of the soils from the dumpsites were moderately acidic (5.66 – 5.92). The soils belong to the textural class: sand. The total organic carbon ranged from high (16.73 g/kg) in the dumpsites from residential area to very high (21.53 g/kg and 29.50 g/kg) in the dumpsites restaurant and learning center respectively. The total nitrogen range from 0.927 g/kg in the dumpsite of residential area to 1.333 g/kg in the dumpsite from learning center. The micro nutrients (Boron, Chlorine, Copper, Iron, Manganese, Molybdenum, Zinc) and heavy metals Lead, Chromium and Cadmium) contents of the soils from the dumpsites and plant samples were generally low and below the permissible range and does not pose any toxicity threat.

CHAPTER ONE

1.0 INTRODUCTION

The environment is the surroundings where humans, plants, animals and micro-organisms live or work. It is composed of the land, the earth's atmosphere and the water. The earth's system is defined by the four sphere, the biosphere (living organism), the atmosphere (air) the lithosphere (land) and the hydrosphere (water), which work in harmony together. Environmental contaminants, as well as pollutants, are chemical that are present at higher levels than the permissible level in any section of the environment (Ibrahim *et al.,* 2017). The pollution of the environment with heavy metals has become a worldwide problem and of scientific concern because the metals are indestructible and most of them have toxic effects on plants and animals (Oronsaye *et al*., 2010).

Celosia (*Celosia argentea* L.) belongs to the pigweed family 'Amaranthaceae'. It is an important leaf vegetable of the South-South Nigeria, which is well known for its succulent leaves rich in protein, vitamins and minerals (Akanbi *et al*., 2017). Its leaves (which slightly mucilaginous) and young shoots are useful in soup and stew preparations which are served with carbohydrate foods such as yam and yam flour, rice e.t.c. More so, *celosia* leaves can be dried and preserved against dry season (Aruna, 2009; Ibrahim *et al.,* 2017). Its uses beyond dietary extend to medicinal purposes and treatment of ailments such as abscesses, cough, diabetes, diarrhea, dysentery, eczema, eye problems, gonorrhea, infected sores, liver ailments, menstruation problems, muscle troubles, skin eruptions, snakebites and wounds (Schippers, 2010; Olubunmi *et al.,* 2018).

In Nigeria particularly Benin City, cultivation and collection of waste from dumpsites as soil amendment is on the increase due to the need for urban gardeners to obtain maximum yield from marginal lands (Taiwo *et al.,* 2013). Vegetables obtained from dumpsites and those grown in urban and peri-urban gardens in Benin City contained high levels of heavy metals (Pb and Cd) (Ogunyemi *e al.,* 2013). However, plants can absorb heavy metals and store in leaves and other edible parts. These metals are then transferred through food consumption to humans and animals. For humans, a high intake of heavy metals can damage organs and increase the risk of cancer (Jan *et al.,* 2010). Metal accumulation in vegetables taken from dumpsite varies significantly from one element to the other (Olufunmilayo *et al*., 2014). Moreover, heavy metals have received the attention of researchers all over the world, mainly due to their harmful effects on plants and other living organisms (Tahar and Keltoum, 2011) but not much has been said about heavy metal content of vegetable raised in Benin City.

1.2 Aim and Objectives

This study therefore seeks to evaluate heavy metals concentration of *Celosia* (C*elosia argentae*) raised on dump site soils in Benin City.

Specific objectives are;

1. Evaluate the chemical and physical properties of the soils from the dumpsite in Benin City and
2. Determine the level of heavy metals content of *Celosia argentae* raised from dumpsite soils in Benin City

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Pollution

Pollution is the introduction of contaminants into the natural environment that cause adverse change (Merriam-Webster, 2010). Pollution can take the form of any substance (solid, liquid, or gas) or energy (such as radioactivity, heat, sound, or light). Pollutants, the components of pollution, can be either foreign substances/energies or naturally occurring contaminants (Dickie, 2022).

Pollution is often classed as point source (coming from a highly concentrated specific site, such as a factory or mine) or nonpoint source pollution (coming from a widespread distributed sources, such as microplastics or agricultural runoff) (Trejos, *et al.,* 2021).

Many sources of pollution were unregulated parts of industrialization during the 19th and 20th centuries until the emergence of environmental regulation and pollution policy in the later half of the 20th century. Sites where historically polluting industries released persistent pollutants may have legacy pollution long after the source of the pollution is stopped. Major forms of pollution include air pollution, light pollution, litter, noise pollution, plastic pollution, soil contamination, radioactive contamination, thermal pollution, visual pollution, and water pollution (Persson *et al.,* 2022).

Pollution has widespread consequences on human and environmental health, having systematic impact on social and economic systems. In 2017, pollution killed nine million people worldwide (one in six deaths), a number unchanged since 2015 (Beil, 2017). Air pollution accounted for 3⁄4 of these earlier deaths (Carrington, 2017). A 2022 literature review found that levels of anthropogenic chemical pollution have exceeded planetary boundaries and now threaten entire ecosystems around the world (Carrington, 2017). Pollutants frequently have outsized impacts on vulnerable populations, such as children and the elderly, and marginalized communities, because polluting industries and toxic waste sites tend to be collocated with populations with less economic and political power (Fuller *et al.,* 2022). This outsized impact is a core reason for the formation of the environmental justice movement (Persson, 2022) and continues to be a core element of environmental conflicts, particularly in the Global South.

Because of the impacts of these chemicals, local, country and international policy have increasingly sought to regulate pollutants, resulting in increasing air and water quality standards, alongside regulation of specific waste streams. Regional and national policy is typically supervised by environmental agencies or ministries, while international efforts are coordinated by the UN Environmental Program and other treaty bodies. Pollution mitigation is an important part of all of the Sustainable Development Goals (Carrington, 2017).

2.2 Environmental pollution

Environmental pollution is one of the major challenges in the modern human society (Ali and Khan, 2017). Environmental contamination and pollution by heavy metals is a threat to the environment and is of serious concern (Ali *et al.,* 2013; Hashem *et al.,* 2017). Environmental pollution caused by heavy metals is increasing along with the increase in the usage of chemicals in industry 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).

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). Pollution of water and soils by heavy metals is an emerging problem 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).

Soil, water and biodiversity are fundamental elements of ecosystem and are the subject of many agrarian, ecological, biological and hydrological studies. A high percentage of ecosystems consist of arable land which is treated with agrochemical products forms the upper layer of the soil. Large quantities of chemical elements infiltrate the water running off of the cultivated soils thereby entering the animal and human food chain (Noltan *et al*., 2005).

The quality of life on earth is inextractably linked to overall quality in the environment. Currently there are two fundamental pollution related problems, the disposal of large quantities of wastes that are continually being produced and the removal of toxic compounds that have been accumulating at dump sites in the soils and in water system over the last few decades (Hsua *et al*., 2006).

Rapid industrialization and urbanization have caused contamination of the environment by heavy metals, and their rates of mobilization and transport in the environment have greatly accelerated since 1940s (Khan *et al.,* 2004; Ali *et al.,* 2019). Their natural sources in the environment include weathering of metal-containing rocks and volcanic eruptions, while principal anthropogenic sources include industrial emissions, mining, smelting, and agricultural activities like application of pesticides and phosphate fertilizers. Combustion of fossil fuels also contributes to the release of heavy metals such as cadmium (Cd) to the environment (Spiegel, 2002). Heavy metals are persistent in the environment, contaminate the food chains, and cause different health problems due to their toxicity. Chronic exposure to heavy metals in the environment is a real threat to living organisms (Wiwanitkit, 2009).

2.3 Heavy Metals

Csuros and Csuros (2002), defined heavy metal is as “a metal with a density greater than 5 g/cm^3 (i.e., specific gravity greater than 5).” According to Duffus (2002), “the term “heavy metals” is often used as a group name for metals and semimetals that have been associated with contamination and potential toxicity or ecotoxicity.” Heavy metals are generally referred to as those metals which possess a specific density of more than 5 g/cm^3 and adversely affect the environment and living organisms (Järup, 2003). Very recently, we have proposed a broader definition for the term, and heavy metals have been defined as “naturally occurring metals having atomic number greater than 20 and an elemental density greater than 5 g/cm^3” (Ali and Khan, 2018).

A heavy metal is not toxic *per se* and it is only toxic when its concentration in the plant and animal exceeds a certain threshold (“it is the dose that makes the effect”). Some elements, called trace elements or micronutrients, have essential functions in plant and animal cells. This has been shown for Co, Cu, Fe, Mn, Mo, Ni and Zn. Only when the internal concentration exceeds a certain threshold that they demonstrate toxic effects, and then they are commonly termed “heavy metals” (Klaus-J, 2010).

Heavy metals are significant environmental pollutants and their toxicity is a problem of increasing significance for ecological, evolutionary, nutritional and environmental reasons (Jaishankar *et al*., 2013).

Heavy metals are one of the important types of contaminants that can be found on the surface and in the tissues of fresh vegetables. Heavy metals rank high amongst the major contaminants of leafy vegetables (Mapanda *et al*., 2005). Zheijazkov and Neilson (2016) found that the concentrations of heavy metals in vegetables per unit dry matter generally follow the order: leaves > fresh fruits > seeds.

The prolonged human consumption of unsafe concentrations of heavy metals in foodstuffs may lead to the disruption of numerous biological and biochemical processes in the human body. Vegetables, especially leafy vegetables grown in heavy metal-contaminated soils, accumulate higher amounts of metals than do those grown in uncontaminated soils (Al Jassir *et al*., 2005).

2.4 Sources of Heavy Metals in the Environment.

Sources of heavy metals in the environment can be both natural/geogenic/lithogenic and anthropogenic. Some natural or geological sources of heavy metals in the environment include weathering of metal-bearing rocks and volcanic eruptions. The global trends of industrialization and urbanization on Earth have led to an increase in the anthropogenic share of heavy metals in the environment (Nagajyoti *et al.,* 2010).

The anthropogenic sources of heavy metals in the environment include mining, industrial and agricultural activities. These metals (heavy metals) are released during mining and extraction of different elements from their respective ores. Heavy metals released to the atmosphere during mining, smelting, and other industrial processes return to the land through dry and wet deposition (Beychok, 2019). Discharge of wastewaters such as industrial effluents and domestic sewage add heavy metals to the environment. Application of chemical fertilizers and combustion of fossil fuels also contribute to the anthropogenic input of heavy metals in the environment. Regarding contents of heavy metals in commercial chemical fertilizers, phosphate fertilizers are particularly important (Hassan, 2019). In general, phosphate fertilizers are produced from phosphate rock (PR) by acidulation. In the acidulation of single superphosphate (SSP), sulfuric acid is used, while in acidulation of triple superphosphate (TSP), phosphoric acid is used (Ali and Khan, 2019). The final product contains all of the heavy metals present as constituents in the phosphate rock (Nica *et al* 2012). Commercial inorganic fertilizers, particularly phosphate fertilizers, can potentially contribute to the global transport of heavy metals (Orisakwe *et al.,* 2012). Heavy metals added to agricultural soils through inorganic fertilizers may leach into groundwater and contaminate it (Mahmood and Malik, 2014) . Phosphate fertilizers are particularly rich in toxic heavy metals. The two main pathways for transfer of toxic heavy metals from phosphate fertilizers to the human body are shown below (Liang, *et al.,* 2016)

(i) Phosphate rock⟶fertilizer⟶soil⟶ plant⟶food⟶human body

(ii) Phosphate rock⟶fertilizer⟶water⟶human body

Combustion of fossil fuels in industries, homes, and transportation is an anthropogenic source of heavy metals. Vehicle traffic is among the major anthropogenic sources of heavy metals such as Cr, Zn, Cd, and Pb (Wang, 2017). Higher concentrations of environmentally important heavy metals have been reported in soils and plants along roads in urban and metropolitan areas. Regarding anthropogenic sources of heavy metals, emissions from coal combustion and other combustion processes are very important (Miedico *et al.,* 2016). During coal combustion, Cd, Pb, and As are partially volatile, while Hg is fully volatile. The anthropogenic sources of Cr include electroplating industries, leather tanneries, textile industries, and steel industries (Ali *et al.,* 2017). Globally, about 50,000 t/year of Cr may be emitted from coal combustion, wood burning, and refuse incineration (Ali and Khan, 2018). Fertilizers also usually contain significant contents of Cr (Ali *et al.,* 2017). Globally, about 60,000 t/year of Ni may be generated from coal combustion; its greater portion remains in the ash (Ali and Khan, 2018). The natural sources of Cd in the environment are volcanic action and weathering of rocks, whereas an anthropogenic source is nonferrous metal mining, especially processing of Pb-Zn ores. Globally, about 7,000 t/year of Cd may be emitted from coal combustion, and sewage sludge incineration is also a source of Cd (Ali and Khan, 2018). Anthropogenic increases in Cd concentrations are also caused by excessive application of chemical fertilizers (Ali *et al.,* 2017). P-containing fertilizers contain Cd as a contaminant at concentrations ranging from trace quantities to 300 ppm on dry weight basis and hence may be a main source of input of this metal to agricultural systems (Kishor *et al.,* 2021). Pb is released to the environment from different sources including acid batteries, old plumbing systems, and lead shots used for hunting of game birds. Combustion of leaded gasoline is also a source of Pb in the environment. Although use of the tetraethyl lead as an antiknock agent in gasoline has been banned, it is still used in some developing regions of the world (Kishor *et al.,* 2021).

2.5 Heavy Metals Contamination of Soils

The heavy metals essentially become contaminants in the soil environments, because:

Their rates of generation via man-made cycles are more rapid relative to natural ones;

They become transferred from mines to random environmental locations where higher potentials of direct exposure occur;

The concentrations of the metals in discarded products are relatively high compared to those in the receiving environment; and

The chemical form (species) in which a metal is found in the receiving environmental system may render it more bioavailable (D‟Amore *et al*., 2005).

A simple mass balance of the heavy metals in the soil can be expressed as follows:

$$Mtotal = (Mp + Ma + Mf + Mag + Mow + Mip) – (Mcr + Ml)$$

where, “M” is the heavy metal, “p” is the parent material, “a” is the atmospheric deposition, “f” is the fertilizer sources, “ag” are the agrochemical sources, “ow” are the organic waste sources, “ip” are other inorganic pollutants, “cr” is crop removal, and “l” is the losses by leaching, volatilization, and so forth (Alloway, 1995; Lombi *et al.,* 2002).

2.6 Sources of Heavy Metal Contamination of Soils

2.6.1 Fertilizer

Agriculture was the first major human influence on the soil (Scragg, 2006). To grow and complete the lifecycle, plants must acquire not only macronutrients (N, P, K, S, Ca, and Mg), but also essential micronutrients. Some soils are deficient in the heavy metals (such as Co, Cu, Fe, Mn, Mo, Ni, and Zn) that are essential for healthy plant growth, and crops may be supplied with these as an addition to the soil or as a foliar spray. Cereal crops grown on Cu deficient soils are occasionally treated with Cu as an addition to the soil, and Mn may similarly be supplied to cereal and root crops (Jones and Jarvis, 2015).

Large quantities of fertilizers are regularly added to soils in intensive farming systems to provide adequate N, P, and K for crop growth. The compounds used to supply these elements contain trace amounts of heavy metals (e.g., Cd and Pb) as impurities, which, after continued fertilizer, application may significantly increase their content in the soil (Jones and Jarvis, 2015). Metals, such as Cd and Pb, have no known physiological activity. Application of certain phosphatic fertilizers inadvertently adds Cd and other potentially toxic elements to the soil, including Hg, and Pb (Jones and Jarvis, 2015).

2.6.2 Pesticides

Several common pesticides used fairly extensively in agriculture and horticulture in the past contained substantial concentrations of metals. For instance in the recent past, about 10% of the chemicals have approved for use as insecticides and fungicides in UK were based on compounds which contain Cu, Hg, Mn, Pb, or Zn. Examples of such pesticides are copper-containing fungicidal sprays such as Bordeaux mixture (copper sulphate) and copper oxychloride (Jones and Jarvis, 2015).

Such contamination has the potential to cause problems, particularly if sites are redeveloped for other agricultural or non-agricultural purposes. Compared with fertilizers, the use of such materials has been more localized, being restricted to particular sites or crops (McLaughlin *et al*., 2000).

2.6.3 Biosolids and Manures

The application of numerous biosolids (e.g. livestock manures, composts, and municipal sewage sludge) to land inadvertently leads to the accumulation of heavy metals such as As, Cd, Cr, Cu, Pb, Hg, Ni, Se, Mo, Zn, Tl, Sb, and so forth, in the soil (Basta *et al*., 2005). Certain animal wastes such as poultry, cattle, and pig manures produced in agriculture are commonly applied to crops and pastures either as solids or slurries (Sumner, 2000). Although most manures are seen as valuable fertilizers, in the pig and poultry industry, the Cu and Zn added to diets as growth promoters and As contained in poultry health products may also have the potential to cause metal contamination of the soil (Sumner, 2000).

The manures produced from animals on such diets contain high concentrations of As, Cu, and Zn and, if repeatedly applied to restricted areas of land, can cause considerable build-up of these metals in the soil in the long run (Sumner, 2000).

Biosolids (sewage sludge) are primarily organic solid products, produced by wastewater treatment processes that can be beneficially recycled (USEPA, 2014). Land application of biosolids materials is a common practice in many countries that allow the reuse of biosolids produced by urban populations (Weggler, 2004). The term sewage sludge is used in many references because of its wide recognition and its regulatory definition.

However, the term biosolids is becoming more common as a replacement for sewage sludge because it is thought to reflect more accurately the beneficial characteristics inherent to sewage sludge (Silveira, 2003). It is estimated that in the United States, more than half of approximately 5.6 million dry tonnes of sewage sludge used or disposed off annually is land applied, and agricultural utilization of biosolids occurs in every region of the country (Sumner, 2000). In the European community, over 30% of the sewage sludge is used as fertilizer in agriculture (Silveira, 2003). In Australia over 175000 tonnes of dry biosolids are produced each year by the major metropolitan authorities, and currently most biosolids applied to agricultural land are used in arable cropping situations where they can be incorporated into the soil (McLaughlin *et al*., 2000). Heavy metals most commonly found in biosolids are Pb, Ni, Cd, Cr, Cu, and Zn, and the metal concentrations are governed by the nature and the intensity of the industrial activity, as well as the type of process employed during the biosolids treatment (Mattigod and Page, 2020). Under certain conditions, metals added to soils in applications of biosolids can be leached downwards through the soil profile and can have the potential to contaminate groundwater (McLaren *et al*., 2014).

2.6.4 Wastewater

The application of municipal and industrial wastewater and related effluents to land dates back 400 years and now is a common practice in many parts of the world (Reed *et al*., 1995). Worldwide, it is estimated that 20 million hectares of arable land are irrigated with waste water. In several Asian and African cities, studies suggest that agriculture based on wastewater irrigation accounts for 50% of the vegetable supply to urban areas (Bjuhr, 2007).

Farmers generally are not bothered about environmental benefits or hazards and are primarily interested in maximizing their yields and profits. Although the metal concentrations in wastewater effluents are usually relatively low, long-term irrigation of land with such can eventually result in heavy metal accumulation in the soil (Bjuhr, 2017).

2.6.5 Metal Mining and Milling Processes and Industrial Wastes

Mining and milling of metal ores coupled with industries have bequeathed many countries, the legacy of wide distribution of metal contaminants in soil. During mining, tailings (heavier and larger particles settled at the bottom of the flotation cell during mining) are directly discharged into natural depressions, including onsite wetlands resulting in elevated concentrations (DeVolder *et al*., 2016). Extensive Pb and Zn ore mining and smelting have resulted in contamination of soil that poses risk to human and ecological health. Many reclamation methods used for these sites are lengthy and expensive and may not restore soil productivity. Soil heavy metal environmental risk to humans is related to bioavailability. Assimilation pathways include the ingestion of plant material grown in (food chain), or the direct ingestion (oral bioavailability) of, contaminated soil (Basta and Gradwohl, 2018).

Other materials are generated by a variety of industries such as textile, tanning, petrochemicals from accidental oil spills or utilization of petroleum-based products, pesticides, and pharmaceutical facilities and are highly variable in composition. Although some are disposed of on land, few have benefits to agriculture or forestry (DeVolder *et al*., 2016). In addition, many are potentially hazardous because of their contents of heavy metals (Cr, Pb, and Zn) or toxic organic compounds and are seldom, if ever, applied to land. Others are very low in plant nutrients or have no soil conditioning properties (Sumner, 2000).

2.6.6 Air-Borne Sources

Airborne sources of metals include stack or duct emissions of air, gas, or vapour streams, and fugitive emissions such as dust from storage areas or waste piles. Metals from airborne sources are generally released as particles contained in the gas stream. Some metals such as As, Cd, and Pb can also volatilize during high-temperature processing. These metals will convert to oxides and condense as fine particles unless a reducing atmosphere is maintained (Smith *et al*., 2015).

2.7 Heavy Metal Contamination of *Celosia argeutae*

Celosia as a vegetable is an important part of a human beings diet because they are a source of nutrients. *Celosia* constitute important functional food components by contributing protein, vitamins, iron, calcium and other nutrients which have marked health effects (Arai, 2002). There is an inherent tendency of plants to take up toxic substances including heavy metals that are subsequently transferred along the food chain (Singh *et al*., 2010). And as such, heavy metal contamination in *Celosia* cannot be underestimated as food stuffs are important components of human diet. Heavy metal contamination of the food items is one of the most important aspects of food quality assurance (Khan *et al*., 2008).

Contamination of foods by heavy metals has become a challenge for producers and consumers. The main sources of heavy metals to vegetable crops are their growth media (soil, air, nutrient solutions) from which these heavy metals are taken up by the roots or foliage (Lokeshwari and Chandrappa, 2006). The toxic and detrimental impacts of heavy metals become apparent only when long-term consumption of contaminated vegetables occurs. Regular monitoring of heavy metals in *Celosia* and other food items should be performed in order to prevent excessive build-up of these heavy metals in the human food chain (Khanna and Khanna, 2011).

Celosia can take up and accumulate heavy metals in quantities high enough to cause clinical problems to humans (Alam *et al*., 2003). Daily metal intake estimate does not take into account the possible metabolic ejection of the metals but can easily tell the possible ingestion rate of a particular metal. Leafy vegetables grown on heavy metal contaminated soils accumulate higher amounts of metals than those grown in uncontaminated soils because of the fact that they absorb these metals through their roots (Sharma *et al*., 2007; Marshall *et al*., 2007). Heavy metals are persistent in the environment and are subject to bioaccumulation in food-chains. They are easily accumulated in the edible parts of leafy vegetables, as compared to grain or fruit crops (Mapanda *et al*., 2005). Some of the heavy metals found in *Celosia are;*

Lead (Pb)

Lead is a toxic element that can be harmful to plants, although 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 (ATSDR, 2007). 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, 2015). 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 tumour 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 (Silbergeld, 2003).

Cadmium (Cd)

Cadmium is one of the big three heavy metal poisons and is not known for any essential biological function. In its compounds, Cd occurs as the divalent Cd (II) ion. Cadmium is directly below Zn in the periodic table and has a chemical similarity to that of Zn, an essential micronutrient for plants and animals. This may account in part for Cd's toxicity; because Zn being an essential trace element, its substitution by Cd may cause the malfunctioning of metabolic processes (Campbell, 2006).

Cadmium is also present as an impurity in several products, including phosphate fertilizers, detergents and refined petroleum products. In addition, acid rain and the resulting acidification of soils and surface waters have increased the geochemical mobility of Cd, and as a result its surface-water concentrations tend to increase as lake water pH decreases (Campbell, 2006).

Cadmium is produced as an inevitable by-product of Zn and occasionally lead refining. The application of agricultural inputs such as fertilizers, pesticides, and biosolids (sewage sludge), the disposal of industrial wastes or the deposition of atmospheric contaminants increases the total concentration of Cd in soils, and the bioavailability of this Cd determines whether plant Cd uptake occurs to a significant degree. Cadmium is very biopersistent, but has few toxicological properties and, once absorbed by an organism, remains resident for many years (Weggler *et al*., 2004).

Since the 1970s, there has been sustained interest in possible exposure of humans to Cd through their food chain, for example, through the consumption of certain species of shellfish or vegetables. Concern regarding this latter 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 deltaaminolevulinic 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).

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, $FeCr_2O_4$. Major sources of Chromium contamination include releases from electroplating processes and the disposal of Cr containing wastes (Smith *et al.*, 2015).

Chromium (VI) is the form of Cr commonly found at contaminated sites. Chromium (VI) can be reduced to Cr (III) by soil organic matter, S^{2-} and Fe^{2+} ions under anaerobic conditions often encountered in deeper groundwater. Major Cr (VI) species include chromate (CrO_4) Land dichromate (Cr_2O). Chromate and dichromate also adsorb on soil surfaces, especially iron and aluminum oxides (Smith *et al.,* 2015).

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).

Arsenic (As)

Arsenic occurs in many minerals, usually in combination with sulfur and metals, but also as a pure elemental crystal. Arsenic is a metalloid. It has various allotropes, but only the grey form, which has a metallic appearance, is important to industry. Arsenic is a common n-type dopant in semiconductor electronic devices. It is also a component of the III–V compound semiconductor gallium arsenide. Arsenic and its compounds, especially the trioxide, are used in the production of pesticides, treated wood products, herbicides, and insecticides. These applications are declining with the increasing recognition of the toxicity of arsenic and its compounds (Tanaka, 2011).

A few species of bacteria are able to use arsenic compounds as respiratory metabolites. Trace quantities of arsenic are an essential dietary element in rats, hamsters, goats, chickens, and presumably other species. A role in human metabolism is not known (Tanaka, 2011). However, arsenic poisoning occurs in multicellular life if quantities are larger than needed. Arsenic contamination of groundwater is a problem that affects millions of people across the world. Some species of bacteria obtain their energy in the absence of oxygen by oxidizing various fuels while reducing arsenate to arsenite. Under oxidative environmental conditions some bacteria use arsenite as fuel, which they oxidize to arsenate (Gibaud and Jaouen, 2010). The enzymes involved are known as arsenate reductases (Asr) (Peryea, 2008).

In 2008, bacteria were discovered that employ a version of photosynthesis in the absence of oxygen with arsenites as electron donors, producing arsenates (just as ordinary photosynthesis uses water as electron donor, producing molecular oxygen). Researchers conjecture that, over the course of history, these photosynthesizing organisms produced the arsenates that allowed the arsenate-reducing bacteria to thrive. One strain, PHS-1, has been isolated and is related to the *gammaproteobacterium Ectothiorhodospira shaposhnikovii*. The mechanism is unknown, but an encoded Asr enzyme may function in reverse to its known homologues (Gibaud and Jaouen, 2010).

In 2011, it was postulated that a strain of Halomonadaceae could be grown in the absence of phosphorus if that element were substituted with arsenic, exploiting the fact that the arsenate and phosphate anions are similar structurally. The study was widely criticised and subsequently refuted by independent researcher groups. Naturally occurring sources of human exposure include volcanic ash, weathering of minerals and ores, and mineralized groundwater. Arsenic is also found in food, water, soil, and air. Arsenic is absorbed by all plants, but is more concentrated in leafy vegetables, rice, apple and grape juice, and seafood. An additional route of exposure is inhalation of atmospheric gases and dusts. During the Victorian era, arsenic was widely used in home decor, especially wallpapers. A study by IIT Kharagpur (2012) found high levels of Arsenic in groundwater of 20% of India's land, exposing more than 250 million people. States such as Punjab, Bihar, West Bengal, Assam, Haryana, Uttar Pradesh, and Gujarat have highest land area exposed to arsenic (Gibaud and Jaouen, 2010).

Copper (Cu)

Copper is an essential nutrient that is incorporated into a number of metalloenzymes involved in haemoglobin formation, drug/xenobiotic metabolism, carbohydrate metabolism, catecholamine biosynthesis, the crosslinking of collagen, elastin, and hair keratin, and the antioxidant defense mechanism. Copper-dependent enzymes, such as cytochrome C oxidase, superoxide dismutase, ferroxidases, monoamine oxidase, and dopamine β- monooxygenase, function to reduce activated symptoms associated with copper deficiency in humans include normocytic, hypochromic anaemia, leukopenia, and osteoporosis (ATSDR, 2004).

Although copper homeostasis plays an important role in the prevention of copper toxicity, exposure to excessive levels of copper can result in a number of adverse health effects including liver and kidney damage, anaemia, immunotoxicity, and developmental toxicity. Many of these effects are consistent with oxidative damage to membranes or macromolecules. Copper can bind to the sulfhydryl groups of several enzymes, such as glucose-6- phosphatase and glutathione reductase, thus interfering with their protection of cells from free radical damage (ATSDR, 2004).

Iron (Fe)

An elevated dietary iron intake enhances the incidence of carcinogen-induced mammary tumors in rats and estrogen-induced kidney tumors in Syrian hamsters. Estrogen administration increases iron accumulation in hamsters and facilitates iron uptake by cells in culture. In humans, increased body stores of iron have been shown to increase the risk of several estrogen-induced cancers (Michael *et al.*, 2009).

Iron acts as a catalytic centre for a broad spectrum of metabolic functions. Iron is also a component of various tissue enzymes, such as the cytochromes, that are critical for energy production, and enzymes necessary for immune system functioning. The fact that serum copper has been found to be low in some cases of iron deficiency anemia suggests that iron status has an effect on copper metabolism (Michael *et al*., 2009).

Iron deficiency includes symptoms such as reduced resistance to infection, reduced work productivity, reduced physical fitness, weakness, fatigue, impaired cognitive function, and reduced learning ability, increased distractibility, impaired reactivity and coordination, itching, inability to regulate body temperature and eating pica (Beard, 2001)

2.8 Effect of heavy metals in soil

Metals can contaminate the general environment through many routes. Because of their stability, they may penetrate environmental compartments, in some cases, many years after the initial deposition pollution of the soil and water systems may also arise from the weathering of disposed product (Nordberg *et al*., 2005). Heavy metal accumulations in plant and soil from natural and artificial sources and subsequent consequences represent important environmental pollution problems. Food safety issues and potential adverse health risks make this one of the most serious environmental concerns (Cui *et al*., 2004).

Some heavy metals such as copper, zinc, manganese, cobalt and molybdenum act as micronutrients for the growth of animals and human beings when present in trace quantities, whereas others such as cadmium, arsenic and chromium acts as carcinogens (Trichopoulos *et al*., 2019). Mercury and lead are associated with the development of abnormalities in children (Gibb and Chen, 2002). Long term intake of cadmium causes renal, prostate and ovarian cancers (Hartwig, 2008).

Generally, at the biochemical levels, the toxic effects caused by excess concentrations of heavy metals include competition for sites with essential metabolites, replacement of essential ions, reactions with –SH groups, damage to cell membranes and reactions with the phosphates groups (Okoronkwo *et al*., 2005).

Soil contamination by heavy metals is of the most important apprehension throughout the industrialization world. Heavy metal pollution not only result in adverse effect of various parameters relating to plant quality and yield but also cause changes in the size, composition and activity of the microbial community (Singh and Kalamdhad,2011).

Heavy metals indirectly affect soil enzymatic activities by shifting the microbial community which synthesize enzymes. Heavy metals exhibit toxic effect towards soil biota by affecting key microbial processes and decrease the number of activities of the soil microorganisms. Conversely, long- term heavy metal effects can increase bacterial community tolerance as well as the tolerance of fungi arbuscular mycorrhizal (AM) fungi, which can play an important role in the restoration of contaminated ecosystem. Chen *et al*, (2002) suggested that heavy metals caused a decrease in bacterial species richness and a relative increase in soil actinomycetes or even decreases in both biomass and diversity of the bacterial communities in contaminated soils.

2.9 Effect of heavy metals on Plants

Some of these heavy metals i.e. As, Cd, Hg, Pb, or Se are not essential for plant growth, since they do not perform any known physiological function in plants. Others i.e. Co, Cu, Fe, Mn, 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 (Jordao, 2006).

Uptake of heavy metals by plants and subsequent accumulation along the food chain is a potential threat to animal and human health. The absorption by plant roots is one of the main routes of entrance of heavy metals in food chain (Mahmood and Malik, 2014). Absorption and accumulation of heavy metals in plant tissue depend upon many factors which include temperature, moisture, organic matter, pH and nutrient availability. The use of compost to improve agricultural yield without caring with possible negative effects might be a problem since the waste compost are most applied to improve soils used to grow vegetables. Considering the edible parts of the plant in most vegetable species, the risk of transference of heavy metals from soil to humans should be a matter of concern (Jordao, 2006).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of the Experimental Location

This study was carried out at the Ugbowo campus of the University of Benin, Benin City in Edo state, Nigeria. The area lies between latitude 6° 23' 37" to 6° 24' 26" North and Longitude 5° 36' 25" to 5° 38' 09" East. It is a segment of the coastal plain sand commonly referred to as the acid sand of Nigeria. The natural climate is humid tropics. The natural vegetation is rainforest. The soil in the area has been mapped as ultisols (Ogeh and Ukodo, 2012). Cloud cover is high (above 89%) during the rainy season and 50-60% in the dry season. Mean annual temperature is about 26.2 ^{0}C and ranges from an average minimum of 21.3 ^{0}C to an average maximum of 31.2 ^{0}C. (NIFOR, 2008).

3.2 Field Sampling and Sample Preparation

Soil samples were collected from three (3) different Dumpsites around the University of Benin, Benin city, Edo State. One (1) each from dump sites located in Residential area, Learning center and Restaurant. Soil samples were taken using a soil auger at identical soil depths (0-15 cm, 15-30 cm). The soil samples were air dried at ambient temperature, crushed by hand in a porcelain mortar and sieved through a 2 mm sieve in the laboratory. Air dried samples were stored in well labeled well labeled polythene bags. The < 2 mm fraction was used for the determination of selected physical and chemical properties as well as the determination of the heavy metal content of the soil.

3.3 Laboratory Analysis

3.3.1 Soil physical properties

Particle size analysis

The mechanical analysis was carried out on the soil samples by the Hydrometer method of Bouyoucos. 50 g of the air-dried 2 mm sieved soil were placed into container of a high-speed stirrer. This was followed by the addition of 50 ml of 20% calgon solution, 3 ml of N sodium hydroxide and 200 ml of water. This was stirred for 3 hours. The content of the container was then transferred to a 1-liter cylinder, diluted to mark and stirred. This was followed by inserting a Bouyoucos soil hydrometer and taking the hydrometer and temperature reading after 40 seconds. Another hydrometer and temperature readings were taken after 2 hours. Percentage sand was calculated from the 40 seconds reading while clay content was obtained from the 2 hrs reading. Percent silt was obtained by subtracting percent sand + clay from 100.

3.3.2 Soil chemical properties

Soil pH

Soil reaction was determined by the aid of a glass electrode pH meter using a soil/liquid ratio of 1:1. This was carried out by weighing 20 g of the 2 mm air dried sample into a 50 ml beaker and adding 20 ml of de-ionized water, stirring the suspension intermittently for 30 mins and reading off the pH value from a previously standardized pH meter.

Exchangeable bases

For Exchangeable cations, 5 g portions of finely ground representative samples were shaken in a conical flask with 100 ml of neutral 1N ammonium acetate for about 1 hour and filtered into plastic cups. The filtrate was used for the determination of sodium (Na^+), Potassium (K^+) by flame photometry while Calcium (Ca^{2+}) and Magnesium (Mg^{++}), were determined by atomic absorption spectroscopy. The concentrations of the cations were calculated after due note of the dilution factors and expressed in centimols per kilogram soil.

Exchangeable Acidity

5 g of pre sieved, air dry soil was weighed into a 150 ml plastic bottle. 50 ml of M KCl was added and the solution was shaken for 1 hour. It was thereafter filtered and 3 drops of phenolphthalein indicator were added to the filtrate. It was titrated against 0.05M NaOH until the colourless solution turned pink.

Effective Cation Exchange Capacity (ECEC)

This was determined by the summation method (Ca +Mg +K + Na + Exchangeable Acidity) and expressed in cmol/kg.

Soil organic carbon

1 g of finely ground representative sample was weighed in duplicate into each beaker followed by the addition of 10 ml of 1N $K_2Cr_2O_7$and rotated gently to wet the soil sample completely. This was followed by the addition of 20 ml of conc. H_2SO_4 using a graduated cylinder, taking a few seconds only in the operation. The beaker was rotated again to effect complete oxidation and allowed to stand for 30 minutes before dilution with distilled water to about 200-250 mL. 5 drops of ferroin were added and the solution was titrated with 0.5N ferrous sulphate solution to wine red end point. Percentage organic matter was calculated by multiplying the value for organic carbon by the Van Bemmeler factor of 1.724.

Total nitrogen

For total Nitrogen**,** 1 g of a representative air dried soil was accurately weighed into Tecator digestion tube and a catalyst mixture containing selenium, $CuSO_4$ and Na_2SO_4 was added followed by 10 ml of concentrated sulphuric acid. The contents of the tube were mixed by gentle shaking and then digested on a Tecator block until the digest became clear. Heating was continued for another one hour before the digest was allowed to cool. The digest was then transferred quantitatively with distilled water to a 100 ml volumetric flask and made up to mark with distilled water. Aliquot of this was analyzed and the percentage Nitrogen content of the soil was then calculated after taking into account, the different dilution factors.

Available phosphorus

Available phosphorus in the soil sample was determined by weighing 5 g of sample into an extraction flask. This was followed by the addition of 35 ml of Bray P-1 extraction solution (0.025N HCl and 0.03N NH_4F and shaking immediately for 1 minute and filtered. 5 mL of the filtrate was then measured into 100 ml volumetric flask and diluted to about 50 ml with distilled water followed by 8 ml of Riley and Murphy (1962) Reagent B solution (1.056 g ascorbic acid in 200 ml molybdate – tartarate solution) and diluted to mark. This was allowed to wait for at least 30 minutes for full colour development before reading at 882 nm. Results obtained from multiplying the OD by the total dilution and the Graph factor (OD X GF X DF) = mg P/kg.

Exchangeable Base (Ca, K and Mg) determination

Calcium and magnesium were determined volumetrically by the EDTA titration procedure described by Black (1965).

10 g of air dried soil was weighed into shaking bottle. 70 ml of IN ammonium acetate solution of pH 7 was added with 100 ml measuring cylinder to extract the exchangeable bases. The bottle was covered tightly and shaken for 1 hour on reciprocal shaker thereafter, the soil suspension was filtered through whatman No 42 filter paper into 100 ml volumetric flask and residue washed into three 10 ml aliquots of IN ammonium acetate of pH 7 solutions.

25 ml aliquot of the filtrate was withdrawn with pipette into 250 ml conical flask, 20 ml of concentrated ammonia solution was added followed by 6 drops of eriochrome black T indicator, the content of the flask was titrated with 0.01 ml of disodium salt of ethylene diamine tetraacetic acid (EDTA) solution and the colour change was sky blue colour as end point. Potassium was determined from the filtrate by flame photometry as described by Black (1965).

Exchangeable Acidity Determination

1 g soil sample was shaken with 100 ml IN KCL for 1 hour on a reciprocal shaker and thereafter filtered through what man No 1 filter paper. 25 ml aliquot of the filtrate was pipetted into a 250 ml conical flask and titrated to a permanent pink end point using 0.01N NaOH and 4 drops of phenolphthalein indicator. Results were expressed as $cmolkg^{-1}$.

Calculation

$$Meq/100g = \frac{N x V x 100}{2.5}$$

Where

N = Normality

V = Litre Volume

2.5 = Weight of soil in aliquot meq/100 = $cmolkg^{-1}$.

Digestion of Soil Samples

The dumpsite soil samples were digested according to Ogunfowokan *et al* (2009). For each sample, 1 g of the sample was digested in Teflon cup with 30 cm^3 aqua - regia (HCL: HNO, 3:1) on a thermostat hot plate at 150 °C. After, about 2 hours of digestion, the Teflon cup with its content was removed from the hot-plate to simmer. Then, 5 cm^3 of concentrated HF added and heated further for 30 min. The Teflon cup with the content was allowed to cool down to room temperature and filtered. After which the filtrate was quantitatively transferred into 50 cm^3

volumetric flask and made up to mark with distilled water. A blank determination was carried out using the procedure described above without the sample. Then Cd, Cr, Cu, Ni and Pb concentrations in the digest were determined using Atomic Absorption Spectrometer (Model - PG 990) in triplicate.

Heavy metals (Aresenic, Chromium, Cadmium and Lead)

1 g of the soil samples was introduced into digesting tubes following the addition of 10 ml concentrated HNO_3. The samples were placed in the digester for 8 h at 96 °C with intermittent stirring. Upon complete digestion, the samples were filtered into 100 ml volumetric flasks using Whatman no. 42 filter paper. The samples were made up to the 100 ml mark in the volumetric flask using distilled deionized water. The concentrations of heavy metals in the supernatant solutions were determined using atomic absorption spectrophotometer (AAS). All samples were analyzed in duplicates.

3.4 Data Analysis

GenStat 12th Edition was used to statistically analyze data obtained from the laboratory analysis and means were separated using Duncan multiple range test at 5% level of probability.

CHAPTER FOUR

RESULT AND DISCUSSION

4.1 Chemical properties of soils from the dumpsites

4.1.1 Soil pH

The result on Table 1 shows that the pH of the dumpsites were moderately acidic. The values were 5.660, 5.707 and 5.917 in learning center, restaurant and residential area dumpsites respectively. The 5.917 recorded in the dumpsites from residential area was significantly ($p<0.05$) different from the others. The moderately acidity condition observed in these dumpsites could be attributed to several factors, including the decomposition of organic matter and the release of organic acids (Marschner, 2012). Furthermore, the variations in the pH values between learning center and both restaurant and residential area dumpsites waste composition, or other local factors that influence soil pH.

4.1.2 Total organic carbon (TOC)

As shown on Table 1, the total organic carbon (TOC) of the dumpsites ranged from high (16.73 g/kg) in the dumpsite from residential area to very high (21.53 g/kg and 29.50 g/kg) in restaurant and learning center respectively. Though no significant ($p\leq0.05$) difference between the TOC in the residential and restaurant dumpsites, but both were significantly ($p<0.05$) less than the 29.50 g/kg recorded in the learning center dumpsite. This finding is consistent with the work of Lal (2004), who also observed high levels of TOC in dumpsite soils. The variations in T.O.C. content may be attributed to differences in waste composition (Blume *et al.*, 2002). Additionally, microbial activity, which is influenced by factors such as temperature and moisture (Six *et al.*, 2002), can play a role in organic matter decomposition, contributing to these variations.

4.1.3 Total Nitrogen

From Table 1, the total nitrogen content of the dumpsites ranged from low (0.927 g/kg) in residential area to moderately low (1.080 g/kg and 1.33 g/kg) in the restaurant and learning center respectively. The 1.333 g/kg recorded in learning dumpsites was significantly ($p<0.05$) higher than 0.927 g/kg recorded in the dumpsites from residential area. The moderate N values may be attributed to the influx of nutrients from the decomposition of organic waste materials (McGrath *et al.*, 2001) and volatilization (Eddy *et al.,* 2006).

4.1.4 Available phosphorus

Available phosphorus (Table 1) was moderate in all the dump sites. The least value (13.07 mg/kg) was recorded in residential area while the highest value (15.50 mg/kg) was recorded in learning center. These shows that there was significant different between the dumpsites (learning center, restaurant, and residential area). These values recorded in this study were lower than those (17.54) reported by Iwegbue *et al.,* (2006). The level of phosphate recorded in this study could be attributed to some decayed plant sources and food substances found at the dumpsite around the dump sites

Table 1: Chemical properties of the soil sample from three dumpsites

Land use	pH	T.O.C. (g/kg)	T.N (g/kg)	Av.P (mg/kg)
Learning center	5.660^{b}	29.50^{a}	1.333^{a}	15.50^{a}
Restaurant	5.707^{b}	21.53^{b}	1.080^{ab}	14.60^{ab}
Residential area	5.917^{a}	16.73^{b}	0.927^{b}	13.07^{b}
SEM	0.0530	1.295	0.0649	0.593
SED	0.0749	1.839	0.0918	0.838
LSD	0.2079	5.083	0.2548	2.328
CV (%)	1.60	9.9	10.1	7.10

Means with same alphabets in the same column are not significantly different at $p < 0.05$

4.2 Gravimetric properties of soils from the dumpsites

The gravimetric prorperties of the dumpsite soils (Table 2) shows that the soils were dominated by the sand fraction. The sand contents were 881.7 g/kg, 880.0 g/kg and 881.0 g/mg in the learning centre, restaurant and residential dumpsites respectively. While the silt content varied from 67.00 g/kg in the dumpsites from both learning centre and residential area to 68.67 g/kg in the restaurant. The clay contents were 51.33 g/kg in the learning centre and restaurant while it was 52.00 g/kg in the residential area. The soil from the dumpsites all belong to the textural class: sand.

4.3 Micronutrient and heavy metal concentration of dumpsite soils

The result shows that Lead (Pb) content (Table 3) of the various dumpsites studied are: learning center (0.827 mg/kg), restaurant (0.980 mg/kg) and Residential area (0.917 mg/kg). Dumpsites of restaurant recorded the highest value. According to the rating of Singh and Steinnes, (2004) the normal average of Pb in soil is given to be (3 mg/kg) and the toxicity range in soil is (100-400 mg/kg). This value shows that Pb content on the dumpsites are below the normal soil range.

The result on Table 3 shows that Cr content across the dumpsites varies from 0.170 mg/kg in learning center to 0.133 mg/kg in restaurant. According to Kabata-Pendias, (2011), the normal range of Chromium in the soil sample is (0.006-18 mg/kg). This means that Cr contents fall between the normal ranges, showing that there is no toxicity effect.

In table 3, Cadmium content of learning centers is (0.220 mg/kg), restaurant value is (0.197 mg/kg), residential area value is (0.200 mg/kg). This shows that Cd has no toxicity effect on the various dumpsites as their contents are below the normal range in the soils. According to Kabata-Pendias (2011), the normal range of Cd in soil is (0.2-0.8 mg/kg)

Table 2:Gravimetric properties of soils from the dumpsites

Land use	Sand	Silt	Clay	Textural class
	→	g/kg	←	
Learning area	881.7^a	67.00^b	51.33^b	Sand
Restaurant	880.0^a	68.67^a	51.33^b	Sand
Residential area	881.0^a	67.00^b	52.00^a	Sand
SEM	1.262	0.192	1.347	
SED	1.785	0.272	1.905	
LSD	4.955	0.756	52.89	
CV (%)	0.2	0.5	4.5	

Means with same alphabets in the same column are not significantly different at $p < 0.05$

Also table 3, shows that content of Iron in the dumpsites are: 107.7 mg/kg in learning center; 119.1 mg/kg in dumpsites of restaurant; 116.9 mg/kg in dumpsites of residential area. Kabata-Pendias, (2011) reported that the normal soil range of Fe is (640-2486 mg/kg). This shows that Iron content of the various dumpsites did not reach toxicity level of the various dumpsite.

Manganese content of *Celosia* in learning center was 14.90 mg/kg; restaurant was 14.03 mg/kg; Residential area was 15.73 mg/kg. The normal Mn range content by soil is given to be (15-100 mg/kg) according to the rating of Brandy and Weil, (2008). The rating shows that Mn content of *Celosia* from these various dumpsites were at normal range.

Copper content of the dumpsite soils (Table 3) has its highest content (33.60 mg/kg) in residential while its least value (30.73 mg/kg) in learning centre. The normal range of Cu in soil is given to be (0.4-45.8 mg/kg) according to the rating of Singh and Steinnes (2004). This shows that there is no toxicity effect of copper on in the various dumpsites soils.

4.4 Heavy metal concentration of *Celosia argentae* shoot raised on dumpsite soils

The result shows that Lead (Pb) content of *Celosia* (Table 4) at the various dumpsites studied are: learning center (0.136 mg/kg), restaurant (0.153 mg/kg) and residential area (0.200 mg/kg). Dumpsites of residential area recorded the highest value. According to the rating of Kabata-Pendias, (2011) the normal average of Pb in plants is given to be (4 mg/kg) and the toxicity range in plant is (40-246 mg/kg). This value shows that Pb content of *Celosia* cultivated on the various dumpsites are below the normal plant range.

The result on Table 4, shows that Cr content across the dumpsites varies from 0.047 mg/kg in learning center to 0.060 mg/kg in restaurant. According to Kabata-Pendias, (2011), the normal

Table 3: Micronutrient and heavy metal concentration of dumpsites soils

	Pb	Cr	Cd	B	Cl	Cu	Fe	Mn	Mo	Zn
Land use	→					(mg/kg)		←		
Learning center	0.827^{a}	0.170^{a}	0.220^{a}	25.43^{a}	28.90^{a}	30.73^{a}	107.7^{b}	14.90^{ab}	16.37^{a}	27.47a
Restaurant	0.980^{a}	0.133^{b}	0.197^{b}	27.13^{a}	30.80^{a}	32.30^{a}	119.1^{a}	14.03^{b}	16.60^{a}	25.10^{b}
Residential	0.917^{a}	0.160^{a}	0.200^{b}	28.20^{a}	30.20^{a}	33.60^{a}	116.9^{a}	15.73^{a}	18.87^{a}	26.10^{ab}
SEM	0.0460	0.0051	0.0051	1.496	1.514	1.269	1.284	0.283	0.302	0.435
SED	0.0650	0.0072	0.0072	2.116	2.142	1.795	1.816	0.401	0.428	0.616
LSD	0.1806	0.0199	0.0199	5.874	5.946	4.984	5.042	1.113	1.188	1.708
CV (%)	8.80	4.3	5.7	9.60	8.80	6.80	1.90	3.30	3.20	2.90

plant range uptake of Chromium is given to be (50-150 mg/kg). This means that Cr contents fall between the normal ranges, showing that there is no toxicity effect.

In Table 4, Cadmium content of learning center is (0.080 mg/kg), restaurant value is (0.090 mg/kg), residential area value is (0.053 mg/kg). This shows that Cd has no toxicity effect on *Celosia* cultivated on the various dumpsites as their contents are below the normal range in the plants. According to Kabata-Pendias (2011), the normal range of Cd in plant is (3-30 mg/kg). This shows that Cd has no toxicity effect on *Celosia* cultivated on the various dumpsites as their contents are below the normal range in the plants.

Table 4 shows that Iron content of learning center is (56.40 mg/kg), restaurant value is (57.43 mg/kg), residential area value is (57.23 mg/kg). The result shows that there was no significant ($p<0.05$) different between the dumpsites. Kabata-Pendias, (2011) reported that the normal plant range of Fe is (20-100 mg/kg). This shows that Iron has no toxicity effect on *Celosia* plant cultivated on the various dumpsites.

Copper content of *Celosia* planted on dumpsite soils (Table 4) has its highest content (21.33 mg/kg) in residential area while its least value (20.00 mg/kg) in restaurant. The normal range of Cu in plant is given to be (10-20 mg/kg) according to the rating of Singh and Steinnes (2004). This shows that there is no toxicity effect of copper in the various dumpsites soils.

Table 4: Micronutrients and heavy metal content of *Celosia argentae* shoot raised on dumpsite soils

	B	Cl	Cu	Fe	Mn	Mo	Zn	Pb	Cd	Cr
Dump site	⟶					(mg/kg)				⟵
Learning center	19.20^{a}	16.80^{a}	21.00^{a}	56.40^{a}	88.67^{a}	9.74^{b}	18.57^{c}	0.136^{b}	0.080^{a}	0.047^{a}
Restaurant	19.90^{a}	15.53^{a}	20.00^{a}	57.43^{a}	90.37^{a}	10.11^{b}	20.67^{b}	0.153^{ab}	0.090^{a}	0.060^{a}
Residential area	22.47^{a}	16.80^{a}	21.33^{a}	57.23^{a}	89.80^{a}	12.60^{a}	21.90^{a}	0.200^{a}	0.053^{b}	0.037^{a}
SEM	1.347	0.270	0.609	0.325	2.72	0.580	0.198	0.0149	0.0061	0.0073
SED	1.905	0.382	0.861	0.459	3.84	0.820	0.280	0.0211	0.0086	0.0104
LSD	5.289	1.062	2.389	1.275	10.67	2.278	0.778	0.0585	0.0239	0.0288
CV (%)	11.4	2.9	5.1	1.0	5.3	9.3	1.7	15.8	14.2	26.6

CHAPTER FIVE

5.0 CONCLUSION

The pH of the soils from the dumpsites were moderately acidic, the total organic carbon was very high, total nitrogen and available phosphorus were moderate. The micronutrients (Copper, Chlorine, Boron, Iron, Manganese, Molybdenum, Zinc) and the heavy metals (Lead, Chromium, and Cadmium) were low and below the permissible range in both soil from the dumpsites and the *Celosia argentae* shoots cultivated on the dumpsites and as such, did not pose any toxicity threat.

REFERENCES

Akanbi, W. B., Togun, A. O., Adediran, J. A. and Ilupeju, D. E. (2017). Growth, dry matter and fruit yields components of okra under organic and inorganic sources of nutrients. *American-Eurasian Journal of Sustainable Agriculture.* 4(1): 1-13.

Al Jassir, C.A., Abah, J., Ubwa, S.T. and Ekele, S. (2005). Soil Availability and Uptake of Some Heavy Metals by ThreeStaple Vegetables Commonly Cultivated along the South Bankof River Benue, Makurdi, Nigeria, *International Journal of Environment and Bioenergy*, 8(2): 56-67.

Alam, M.G., Snow, E.T. and Tanaka, A. (2003). Arsenic and heavy metal contamination of vegetables grown in samta village, Bangladesh.Science Total Environment, 308(1-3), 83-96.

Ali, H. and E. Khan, (2018). "What are heavy metals? Long-standing controversy over the scientific use of the term' heavy metals'- proposal of a comprehensive definition," *Toxicological &Environmental Chemistry*, vol. 100, no. 1, pp. 6–19.

Ali, M.J. and Khan, M.A. (2017). Heavy metal pollution threatens terrestrial, ffects of silicon onalleviation of manganese toxicity of rice plants. Soil Science andPlant Nutrition34:65–73

Ali; Saleem, Mohammad; Mustafa, Ghulam; Ashraf, Moneeb; Saleem, Ammara; Akhtar, Bushra (2019). "Association of textile industry effluent with mutagenicity and its toxic health implications upon acute and sub-chronic exposure". Environmental Monitoring and Assessment. 190 (3): 179. doi:10.1007/s10661-018-6569-7. ISSN 1573-2959. PMID 29492685. S2CID 3710964.

Alloway, B.J. (1995). Heavy Metals in Soils, Blackie Academic andProfessional, London, UK, 2nd edition, 1995.

Arai, S. (2002). Global view onfunctional foods: Asian perspectives. British Journal of Nutrition, 88(2), S139-S143

Aruna, B. C. Walpola, and M.-H. Yoon, (2009). "Current status of heavy metal contamination in Asia's rice lands," Reviews in Environmental Science and Bio/Technology, vol. 12, no. 4, pp. 355–377.

ATSDR (2004). Toxicological Profile for Copper. Atlanta, Georgia, UnitedStates. US Department of Health and Human Services. Agency forToxic Substances and Disease Registry.

ATSDR (2007). Toxicology profile for Lead. Atlanta, Georgia, United States.US Department of Health and Human Services. Agency for ToxicSubstances and Disease Registry.

Basta, N.T. and Gradwohl, R. (2018).Remediation of heavy metal contaminated soil using rock phosphate, Better Crops, 82(4):29–31.

Basta, N.T., Ryan, J.A. and Chaney, R.L. (2005). Trace element chemistry in residual-treated soil: key concepts and metal bioavailability*, Journal of Environmental Quality*, 34(1):49–63.

Beard, J.L. (2001). Iron biology in immune function, muscle metabolism and neuronal functioning. *Journal of Nutrition*, 131(2S-2), 568S-579S

Beil, L. (2017). "Pollution killed 9 million people in 2015". Science News. Retrieved 1 December 2017.

Beychok, M. R. (2019). "A data base for dioxin and furan emissions from refuse incinerators". Atmospheric Environment. 21 (1): 29–36. Bibcode:1987AtmEn..21...29B. doi:10.1016/0004-6981(87)90267-8.

Bjuhr, J. (2007). Trace Metals in Soils Irrigated with Waste Water in a Periurban Area Downstream Hanoi City, Vietnam, Seminar Paper, Institutionen for markvetenskap, Sveriges lantbruk- suniversitet (SLU), Uppsala, Sweden.

Black CA. (1965). Methods of soil analysis. American Society of Agronomy, Madison, Wisconsin Argon. 562-563.

Blume, H. P., Brümmer, G. W. and Fleige, H. (2002). *Scheffer/Schachtschabel Soil Science* (12th ed.). Springer.

Brady, N. C. and Weil, R. R. (2008). *The Nature and Properties of Soils* (14th ed.). Prentice Hall.

Campbell, (P.G.C. (2006). Cadmium-A priority pollutant, Environmental Chemistry, 3(6):387–388.

Carrington, D. (2017). "Global pollution kills 9m a year and threatens 'survival of human societies'". The Guardian. Retrieved October 20, 2017.

Chen, Pen-Yuan; Wilkie, Jennifer A.; Elimelech, Menachem (2002). "Arsenic Removal from Drinking Water during Coagulation". Journal of Environmental Engineering. 123 (8): 800–807. doi:10.1061/(ASCE)0733-9372(1997)123:8(800). ISSN 0733-9372.

Csuros, M. and Csuros, C. (2002). Environmental Sampling and Analysis for Metals, Lewis Publishers, Boca Raton, FL, USA.

Cui, Z., Zhang, H., Chen, X., Zhang, C., Ma, W., Huang, C., ... and Dou, Z. (2004). Pursuing sustainable productivity with millions of smallholder farmers. Nature, 576(7787), 1-5.

D‟Amore, J.J., Al-Abed, S.R., Scheckel, K.G. and Ryan, J.A. (2005).Methods for speciation of metals in soils: a review, *Journal of Environmental Quality*, 34(5):1707–1745

DeVolder, P.S., Brown, S.L., Hesterberg, D. and Pandya, K. (2003).Metal bioavailability and speciation in a wetland tailings repository amended with biosolids compost, wood ash, and sulfate, *Journal of Environmental Quality*, 32(3):851–864

Dickie, G. (2022). "Pollution killing 9 million people a year, Africa hardest hit - study". Reuters. Retrieved 23 June 2022.

Duffus, J.H. (2002). “Heavy metals” a meaningless term? (IUPAC Technical Report),” Pure and Applied Chemistry, vol. 74, no. 5, pp. 793–807, 2002.

Eddy, N.O., Odoemelem, S.A. and Mbaba, A. (2006). Elemental composition of osil in some dumpsites. *Electronic Journal of Environmental Agricultural And Food Chemistry* 5(3):1015-1031.

Fuller, R., Landrigan, P. J, Balakrishnan, K., Bathan, G., Bose-O'Reilly, S., Brauer, M., Caravanos, J., Chiles, T., Cohen, A., Corra, L., Cropper, M., Ferraro, G., Hanna, J., Hanrahan, D., Hu, H., Hunter, D., Janata, G., Kupka, R., Lanphear, B., Lichtveld, M., Martin, K., Mustapha, A., Sanchez-Triana, E., Sandilya, K., Schaefli, L., Shaw, J., Seddon, J., Suk, W., Téllez-Rojo, M. M. and Yan, C. (2022). "Pollution and health: a progress update". The Lancet Planetary Health. 6 (6): e535–e547. doi:10.1016/S2542-5196(22)00090-0. PMID 35594895. S2CID 248905224.

Gibaud, S. and Jaouen, G. (2010). Arsenic – based drugs: from Fowler's solution to modern anticancer chemotherapy. Topics in Organometallic Chemistry. Vol. 32. pp. 1–20. Bibcode:2010moc..book....1G. doi:10.1007/978-3-642-13185-1_1. ISBN 978-3-642-13184-4.

Gibb, S. L. and Clien, L.W. (2002). Toxicology of Metals. Boca Raton. FL, USA: CRC Press.

Hartwig, A. (2008). Carcinogenicity of metal compounds: Possible role of DNA repair inhibition. Toxicology Letters, 102-103, 235-239.

Hashem, M.H. Rashed, T.S Hoque , M.M.M Jahangir M.A (2017). Manganese as a micronutrients in Agriculture , crop requirement and management.

Hassan, S. (2019). "Pervasive Pollution Problems Caused by Plastics and its Degradation". *International Journal of Online and Biomedical Engineering.* 15 (10): 29–39.

Hsua, M.J., Selvaraj, B.K. and Agoramoorthy, G. (2006), Taiwan‟s Industrial Heavy metal pollution threatens terrestrial Biota, Environmental Pollution, 143(2): 327-334

Huguet, N.F., Bosch, C., Lourencetti, C., Nadal, M., Schumacher, M., Grimalt, J.O. and Domeingo, J.L. (2009), Human health risk assessment of environmental exposure to organochlorine compounds in the catalan stretea of the Ebro River, Spain, Bulletin of Environmental contamination and Toxicology, 83: 662-667

Ibrahim A,, Abduselam F., Assefa A., Babajide, P.A. and Olla, N.O. (2017). Performance of indigenous Celosia argentea variety and soil physico-chemical properties as affected by dual application of compost and single N-mineral fertilizer in Southern Guinea Savanna vegetation zone of Nigeria. *Journal of Biology, Agriculture and Healthcare*. 4(19):69-74

Iwegbue, C. M. A., Isirimah, N.O., Igwe, C., and Walham, E.S. (2006). Characterististics levels of Heavy Metals in soil Profiles of Automobile Mechanic Waste Dumps in Nigeria. Environmentalist, 26, 131-137

Jaishankar, M., Mathew, B.B., Shah, M.S. and Gowda, K.R.S. (2013). Biosorption of Few Heavy Metal Ions Using Agricultural Wastes. *Journal of Environment Pollution and Human Health,* 2(1):1–6.

Jan, L.J.M., Di Gregorio, A., and Rosier,R.N., (2010) A new concept for a land covers a classification system. The Land, 2 (1), 55–65

Jarup, L. (2003). Hazards of heavy metal contamination, British Medical Bulletin, 68: 167–182.

Jones, L. and Jarvis, M.T. (2015). Chemistry—Molecules, Matter and Change, W. H. Freeman, New York, NY, USA, 3rd edition.

Jordao, E.T. (2006) "Study on heavy metals levels and its risk assessment in some edible fishes from Bangshi River, Savar, Dhaka, Bangladesh," *Food Chemistry*, 134: (4), 1847–1854.

Kabata-Pendias, A. (2011). Trace Elements in Soils and Plants (4th ed.). CRC Press.

Khan, S., Cao, Q., Zheng, Y.M., Huang, Y.Z. and Zhu, Y.G. (2008). Health risk of heavy metals in contaminated soils and food crops irrigated with waste water in Beijing, China. Environmental Pollution Series, 152(3):686-692.

Khanna, S. and Khanna, P. (2011). Assessment of Heavy Metal Contamination in Different Vegetables Grown in and Around Urban Areas. *Research Journal of Environmental Toxicology*, 5:162-179

Kharagpur, III. (2012). Study Finds 20% of India Has High Arsenic Levels in Groundwater". The Wire. PTI. . Retrieved 23 May 2023.

Kishor, R., Purchase, D., Saratale, G. D., Saratale, R. G., Ferreira, L. F. R., Bilal, M., Chandra, R. and Bharagava, R. N. (2021). "Ecotoxicological and health concerns of persistent coloring pollutants of textile industry wastewater and treatment approaches for environmental safety" . *Journal of Environmental Chemical Engineering.* 9 (2): 105012.

Klaus-J.A. (2010). Definition of "Heavy Metals" and their role in biological systems. In: Sherameti, I. and Varma, A. (eds.) Soil Heavy Metals, Soil Biology. Germany: Springer Verlag Berlin Heidelberg.

Lal, R. (2004). Soil carbon sequestration impacts on global climate change and food security. Science, 304(5677), 1623-1627.

Liang,S.I., Gao, N, Li, Z. C., Shen, S.G. and Li, J. (2016). "Investigation of correlativity between heavy metals concentration in indigenous plants and combined pollution soils," Chemistry and Ecology, vol. 32, no. 9, pp. 872–883, 2016.

Lokeshwari, H. and Chandrappa, G.T. (2006). Impact of heavy metal contamination of Bellandur Lake on soil and cultivated vegetation, Current science, 91, 622-627.

Lombi, E.; Zhao, F.-J.; Fuhrmann, M.; Ma, L. Q.; McGrath, S. P. (2002). "Arsenic Distribution and Speciation in the Fronds of the Hyperaccumulator Pteris vittata". New Phytologist. 156 (2): 195–203.

Mahmood, A and R. N. Malik, (2014). "Human health risk assessment of heavy metals via consumption of contaminated vegetables collected from different irrigation sources in Lahore, Pakistan," *Arabian Journal of Chemistry*, vol. 7, no. 1, pp. 91–99, 2014.

Manahan, S.E. (2003). Toxicological Chemistry and Biochemistry, CRC Press, Limited Liability Company (LLC), 3rd edition

Mapanda, F., Mangwayana, E.N., Nyamangara, J. and Giller, K.E. (2005). The effect of long-term irrigation using waste water on heavy metal contents of soils under vegetables in Harare, Zimbabwe. Agricultural, Ecosystems and Environment, 107:151-165.

Marschner, H. (2012). Mineral Nutrition of Higher Plants (3rd ed.). Academic Press.

Marshall, F.M., Holden, J., Ghose, C., Chisala, B., Kapungwe, E., Volk, J., Agrawal, M., Agrawal, R., Sharma, R.K. and Singh, R.P. (2007). Contaminated Irrigation Water and Food Safety for the Urban and Peri-urban Poor. Appropriate Measures for Monitoring and Control from Field Research in India and Zambia. University of Sussex.

Mattigod, S.V. and Page, A.L. (1983). Assessment of metal pollution in soil, in Applied Environmental Geochemistry, Academic Press, London, UK, pp. 355–394.

McGrath, S. P., Lombi, E., Zhao, F.-J., Fuhrmann, M. and Ma, L. Q. (2001). "Arsenic Distribution and Speciation in the Fronds of the Hyperaccumulator Pteris vittata". New Phytologist. 15 (1): 15–20.

McLaren, R.G., Clucas, L.M. and Taylor, M.D. (2014). Leaching of macronutrients and metals from undisturbed soils treated with metal-spiked sewage sludge, Australian Journal of Soil Research, 43(2):159–170.

McLaughlin, M.J., Weggler, K. and Graham, R.D. (2000). Effect of Chloride in Soil Solution on the Plant Availability of Biosolid-Borne Cadmium, *Journal of Environmental Quality,* 33(2):496–504

Merriam-Webster, (2010)."Pollution – Definition from the Merriam-Webster Online Dictionary"-08-13. Retrieved 2010-08-26.

Michael, J.; Hernandez, Alexandra L.; Beeris, Martin; Smith, Meera M.; Moore, Lee E. (2009). Kaufman, Joel D.; Boyd, Windy A.; Callahan, Catherine L.; Schroeder, Jane C.; Warren, Julia Boyle; Woolard, Susan Booker (eds.). "Arsenic-induced skin lesions among Atacameño people in Northern Chile despite good nutrition and centuries of exposure" *Journal of Environmental Health Perspectives*. 108 (7): 617–620

Miedico, O. Ferrara, A. Tarallo, M. Pompa, C. Bisceglia, D. and Chiaravalle, A.E. (2016). "Hazardous and essential trace elements profile in the different soft tissues of Lithophaga lithophaga (Linnaeus, 1758) from Southern Adriatic Sea (Italy)," Toxicological & Environmental Chemistry, vol. 98, no. 8, pp. 877–885.

Nagajyoti, P.C. Lee, K. D. and Sreekanth, T. V. M. (2010). "Heavy metals, occurrence and toxicity for plants: a review," Environmental Chemistry Letters, vol. 8, no. 3, pp. 199–216.

Nica, M.O. West, M., Ellis, A.T., Potts, P.J., Streli, C., Vanhoof, C., Wegrzynek, D. and Wobrauschek, P. (2012). Atomic spectrometry update. X-Rayfluorescence spectrometry. *Journal of AnalyticalAtomicSpectrometry*,24:1503–1545.

NIFOR (2008). Weather Data (Temperature, Rainfall and Relative Humidity). 1993 – 2011. Nigerian Institute For Oil-Palm Research Main Station, Benin City, Nigeria.

Noltan, M.J.M., Oosthoek, A.J.P., Rozema, J. and Aerts, R. (2005), Heavy metal concentrations in a soil plant snail food chain along a terrestrial soil pollution gradient, Environmental Pollution, 138(1):178-190.

Nordberg, G.F., Fowler, B.A., Nordberg, M. and Friberg, L. (2005). Handbook on the Toxicology of Metals.

Ogeh, J. S. and Ukodo, E. (2012). Profile Distribution of Physical and Chemical Properties in Soils of a Toposequence in Benin, Rainforest of Nigeria. *Nigerian Journal of Basic and Applied Science*, 20(1): 68-72

Ogunyemi, S., Togun, A. O. and Ladipo D.O. 213. Studies on some nursery management techniques for *Irvingia wombulu* (Syn. Exolia) ex. Okafor. *Nig. J. Ecol*. 3: 24-28.

Okoronkwo, N.E., Ano, A.O. and Onwuchekwa, E.C. (2005). Environment, health and risk assessment: a case study of the use of an abandoned municipal waste dump site for agricultural purposes. *African Journal of Biotechnology*, 4:1217-1221.

Olubunmi, F.L., Abah, J., Abdurahaman, F.I., Ndahi, N.P. and Ogugbuaja, V O. (2018). Effects of inorganicfertilizers and herbicides on levels of some heavy metals in soils and grains of rice grown inselected areas of Benue State, Nigeria. *International Journal of Applied and Resources Technology,* 1: 160-166.

Olufunmilayo, O.O., Adesanya-Davies, F. and Gebeyaw, T. (2014). Soil fertility status as influenced by different land uses in Maybar areas of South Wello zone, North Ethiopia. Degree of Master of Science in agriculture (soil science). Haramaya University. p143-150.

Oronsaye, E., Herawati N, Suzuki S, Hayashi K, Rivai IF, Koyoma H. (2010). Cadmium, copper and zinc levels in rice and soil of Japan, Indonesia and China by soil type. Bull EnvContamToxicol. 64:33–39.

Palaniappan, P.L.R.M.,Krishnakumar, N. and Vadivelu, M. (2009), Bioaccumulation of lead and the influence of chelating agents in Catla catla fingerlings, Environ Chem Lett., 7: 51-54

Persson, L., Carney, J., Almroth, B.M., Collins, C.D., Cornell, S., de Wit, C.A. and Diamond M.L. (2022). "Outside the Safe Operating Space of the Planetary Boundary for Novel Entities". Environmental Science & Technology. 56 (3): 1510–1521. Bibcode:2022EnST...56.1510P. doi:10.1021/acs.est.1c04158. PMC 8811958. PMID 35038861.

Peryea, F. J. (2008). Historical use of lead arsenate insecticides, resulting in soil contamination and implications for soil remediation. 16th World Congress of Soil Science. Montpellier, France. Archived from the original on 7 December 2008.

Reed, S.C., Crites, R.W. and Middlebrooks, E.J. (1995). Natural Systems for Waste Management and Treatment, McGraw-Hill, New York, NY, USA, 2nd edition.

Riley J.P. and Murphy, J. (1962). A modified single solution method for determination of phosphate in natural waters. Anal. Chem. Acta. 42:31–36.

Schippers, R.R. (2010). African Indigenous Vegetable. pp. 56-60. An Overview of the Cultivated species. Chatthan, U.K., N.R/ACO. Eropean Union.

Scragg, A. (2006). Environmental Biotechnology, Oxford University Press, Oxford, UK, 2nd edition.

Sharma, R.K., Agrawal, M. and Marshall, F.M. (2007). Heavy metals contamination of soil and vegetables in suburban areas of Varanasi, India. Ecotoxicology and Environmental Safety, 66:258-266.

Silbergeld, E.K. (2003). Facilitative mechanisms of lead as a carcinogen.Mutation Research, 533, 121-133.

Silveira, M.L.A., Alleoni, L.R.F. and Guilherme, L.R.G. (2003). Biosolids and heavy metals in soils, Scientia Agricola, 60(4): 64–111.

Singh, A., Sharma, R.K., Agrawal, M. and Marshall, F.M. (2010).Risk assessment of heavy metal toxicity through contaminated vegetables from waste water irrigated area of Varanasi, India.International Society for Tropical Ecology, 51:375-387

Singh, B. R. and Steinnes, L.S. (2004). “Accumulation of heavy metals in soils and plants after long-term use of fertilizers and fungicides in Tanzania,” Fertilizer Research, vol. 44, no. 3, pp. 241–248.

Singh, R. D. and Kalamdhad C. K.; (2011). "Technological options for the removal of arsenic with special reference to South East Asia". Journal of Environmental Management. 107: 1–8. doi:10.1016/j.jenvman.2012.04.016. PMID 22579769.

Smith, E., Naidu, R. and Alston, A. M. (2015). Boron adsorption-desorption in soils: The role of pH and competing ions. *Journal of Colloid and Interface Science*, 139(2), 481-490.

Sumner, (2000). Cation exchange capacity and exchange coefficients. In D. L. Sparks (Ed.), Methods of Soil Analysis. Part 3: Chemical Methods *American Society of Agronomy, Inc.* pp. 1201-1230.

Tahar, M. and Keltpum, S.O.P.(2011). Heavy metal levels of some fruits and leafy vegetables. Journal of Food Science,3(1):89-93

Taiwo, E. Adewole, M.B. and Uchegbu, L.U. (2013). Properties of Soils and Plants Uptake within the Vicinity of SelectedAutomobile Workshops in Ile-Ife, South Western Nigeria, Ethiopian Journal of Environmental Studiesand Management, 3(3):23-28.

Tanaka, A. A. M. Yousafzai, F. Ullah, F. Bari (2011).“Bioaccumulation of some heavy metals: analysis and comparison of Cyprinus carpio and Labeo rohita from Sardaryab, Khyber Pakhtunkhwa,” BioMed Research International, vol. (1) 5p.

Trejos, Erika M.; Silva, Luis F. O.; Hower, James C.; Flores, Eriko M. M.; González, Carlos Mario; Pachón, Jorge E.; Aristizábal, Beatriz H. (2021). "Volcanic emissions and atmospheric pollution: A study of nanoparticles". Geoscience Frontiers. 12 (2): 746–755. doi:10.1016/j.gsf.2020.08.013. ISSN 1674-9871. S2CID 224936937.

Trichopoulos, D., Lipworth, L., Petridou, E. and Adami, H.O. (2019). Epidemiology of Cancer, Philadelphia, Lippincott Company

USEPA (2014). Treatment technologies for site cleanup: annual status report (12th Edition), Tech. Rep. EPA-542-R-07-012,Solid Waste and Emergency Response (5203P), Washington,DC, USA,

Wang, Y.W. (2017). “Distribution of anthropogenic cadmium and arsenic in arable land soils of Hainan, China,” Toxicological & Environmental Chemistry, vol. 97, no. 3-4, pp. 402–408.

Weggler, K., McLaughlin, M.J. and Graham, R.D. (2004). Effect of Chloride in Soil Solution on the Plant Availability of Biosolid-Borne Cadmium, *Journal of Environmental Quality*, 33(2):496–504.

Wierzbicka, M. (2015). How lead loses its toxicity to plants. Acta SocietatisBotanicorum Poloniae, 64:81-90.Wiwanitkit, V. (2009). A review of mercury contamination in marine faunain Thailand. Toxicological & Environmental Chemistry, 91:53-55.World Bank (2002). What Do We Know About Air Pollution? India Case Study, Urban Air Pollution, South Asia Urban Air Quality ManagementBriefing Note, 4:1-4.

Xi, X.Z., Xin, T.J., Duan, L.X. and Pei, J. (2009), Isolation, identification and characterization of cadmium resistant Pseudomonas aeruginosa strain, *Journal of Central South University Technology*, 16:416-421.

Zheijazkov, V.D. and Nielsen, N.E. (2016). Effect of heavy metals on peppermint and cornmint. Plant and Soil, 178:59-66.