AKENTEN APPIAH - MENKA UNIVERSITY OF SKILLS TRAINING AND ENTREPRENEURIAL DEVELOPMENT

MPHIL THESIS

ASSESSMENT OF HAZARDOUS METALS IN SOILS AND MEDICINAL PLANT SAMPLES FROM AHAFO ANO - NORTH MUNICIPALITY.

EBENEZER APPIAH

BSc. CHEMISTRY (HONS)

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A Thesis submitted to the Department of Chemistry Education of the Faculty Science Education, Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development, in Partial Fulfillment of the Requirement for the Award of a Master of Philosophy in Chemistry.

NOVEMBER, 2024

DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of my own original work and that no part of it has been presented for another degree at this university or elsewhere.

Candidate's Name: Ebenezer Appiah

Signature: ……………………………………. Date: …………………………….

Supervisor's Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development

Principal Supervisor's: Name: Prof. Kofi Sarpong

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Signature ……………………………………….. Date ……………………………

ABSTRACT

Indiscriminate anthropogenic activities such as mining and some farming practices have resulted in elevated levels of heavy metals in the environment. The heavy metals in the environment bio concentrate in medicinal plants through absorption from the soil. This study was carried out to assess the extent of heavy metals (Pb, Cd, Cu, Zn, and Mn) accumulation in medicinal plants commonly used in Ahafo – Ano North Municipality of Ghana by employing atomic absorption spectrometry. The levels of metals in different plant parts were found not to be statistically significantly different ($P > 0.05$). The findings indicate the presence of heavy metals in all the medicinal plants and their immediate soils were below the World Health Organization and Food and Agriculture standards. The geo-accumulation index estimated to evaluate the extent of contamination showed that the soils in the Tepa area have moderate to high degree of contamination and this may be due to anthropogenic activities. HI and HQ were below 1, indicating no human health risk associated with the exposure of these metals at the current concentrations. Notwithstanding, due to bio-accumulation effects of metals on medicinal plants, continuous studies is needed to safeguard the medicinal plants in the area.

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DEDICATION

To my dear wife Janet Twumasiwaa Agyemang, my lovely mother Cecilia Yeboah and children Sampson Kofi Yeboah, Melody Nyamedea Sarfowaa Appiah and Marigold Nyameye Yeboaa Appiah this thesis is dedicated with deepest gratitude.

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CHAPTER ONE

INTRODUCTION

1.1 Background Information

Majority of Ghanaians live beneath the poverty line. Thus, between 60 - 70% are unable to access the conventional medical care and other standard health-care systems (WHO, 2009). For such population, medicinal plants can provide a cheaper, accessible and sustainable source of medical care. Medicinal plants that can improve the immune system would be of great benefit to these people since their use would result in less infections and speedy recovery from diseases (WHO, 1992). It has been estimated by the World Health Organization (WHO) that 80% of the population in developing countries such as Ghana presently use herbal medicine to meet their primary health care needs (Sadhu et al., 2015). Medicinal plants play an important role in traditional medicine and are widely consumed as home remedies. Medicinal plants are plants with known medicinal properties and they serve as alternative source of medicine (Sadhu et al., 2015). These plants differ from the other plants in that they have a noted pharmacological effect on the health of a human being and animals when administered (Lokhande et al., 2009). These medicinal plants are used in preparations such as solutions, ointments, tablets and capsules and are used as prescribed. Some methods used for plant parts preparation are maceration, infusion and decoction (Karahan, 2023).

Hazardous metals specifically heavy metals are metals of atomic weights 63.5 – 200.6 g/mol and a specific gravity greater than $5 g/cm^3$ (Sadhu et al., 2015). These metals referred to as heavy metals can cause damaging effects even at very low concentrations; they therefore tend to accumulate in the food chain and in the human body (Gyamfi et al., 2023). Exposure to these elements may lead to numerous human health implications such as development retardation or malformations, kidney damages, cancers, abortion, effect on intelligence and behavior, and at worse death in some cases of exposure to very high concentrations (Agyarko et al., 2011). Polluted environments produce contaminated plant materials and products which may be harmful to the health of the consumer. Soils may become polluted by the accumulation of hazardous metals through emissions from the massively expanding industrial areas, mine tailings, disposal of high metal wastes from metropolitan and municipal wastes, leaded gasoline and paints, land application of fertilizers, animal manures, sewage sludge, pesticides used in agriculture, coal combustion residues, spillage of petrochemicals, and atmospheric deposition refuse burning, heavy-duty electric power generator emissions, automobile exhaust (Wuana & Okieimen, 2011). Other factors include the climate conditions, irrigation with wastewater, and absorptive capacity of the plant (Baloch, 2021). Heavy metals constitute an ill-defined class of inorganic chemical hazards, and those most commonly found at contaminated sites are zinc (Zn), manganese (Mn), lead (Pb), cadmium (Cd), copper (Cu) for the purpose of this present study. Heavy metals can accumulate and relocate within the soil environment. Metal pollutants in the soil may be absorbed by the medicinal plants through their roots and vascular system. (Macrostachyus, 2015). The factors that influence the accumulation and concentrations of hazardous metals in a plant include atmospheric depositions, bioavailability of hazardous metals in the soil, soils physicochemical properties (pH, conductivity and organic matter concentration), and where the plant is grown. With these factors besides with the harvesting and manufacturing conditions can collectively affect the heavy metal content and hence the safety of herbal medicines (Chase, 2017).

The harmful effects of these heavy metals can be manifested directly or indirectly by way of binding with phytopharmacologically active substances of herbal drugs which intend results in their consumption. Heavy metals may also affect the pharmacokinetics of the drug. It is possible that ingesting herbal drugs obtained from contaminated sources will lead to serious health implications (Mishra et al., 2010). These heavy metals are highly reactive in nature and form complexes with other species such as oxygen, sulfide, and chloride by which they bring to bear their toxicity. Heavy metals not like organic contaminants which can then be oxidized to carbon (IV) oxide by microbial activities, their total concentration in soils remains for a longer period after they have been introduced. The occurrence of hazardous metals in the soil can extremely inhibit the biodegradation of organic pollutants or contaminants (Wuana & Okieimen, 2011). Speciation of these metals that is changes in their chemical forms and their bioavailability are in whatever way possible (Zhang et al., 2017). Continuous exposure to these hazardous elements causes their retention and internal imbalances within the human body, which eventually starts using them as substitutes for essential elements (Sadhu et al., 2015). Soils contaminated with elevated levels of heavy metal concentration can easily be taken up and contaminate plants, animals and human beings upon exposure to them. So far soil is considered the major reservoir of heavy metals, thus the extent of heavy metal transfer from soil to plant has to be studied (Konieczynski et al., 2022). The pharmacological effect of these medicinal plants completely depends on the chemical constituents present in these plants (Sarpong & Dartey, 2017).

1.2 Problem statement

Most medicinal plants are not mainly cultivated but they are taken from the wild (Shinwari, 2010). The recent increase in illegal mining activities introduces hazardous metals into the soil. The application of pesticides and fertilizers to farms from which the plants are directly obtained from possibly affects the transfer of heavy metals into medicinal plants**.** There is also the possibility of heavy metal transfer in the method employed in the crushing of the raw plant materials.

In as much as medicinal plants has gain acceptance locally and throughout the world, there has been cases of medicinal plant products causing adverse reactions due to the presence of heavy metals (Sarpong et al., 2022). Ayurvedic medicines made from these plants are commonly used in humans both young and old in the treatment of varieties of diseases. It has been estimated that about 70% of the population in developing countries including Ghana presently use herbal medicine to meet their primary health care needs. However, higher levels of hazardous metals in medicinal plants becomes accumulated overtime in the body and can cause damage to the human body including kidney, cardiovascular system, cancers and sometimes death. In Ghana, cases of adverse health implications suspected to have been caused by medicinal products has been reported by Sarpong et al.,(2022). The search for active ingredients and heavy metal contaminants in plant materials by phyto-chemists, pharmacists and chemists has been going on for a long time. However, there has not been much research into the possible transfer of heavy metals from the varied processes that are employed in the crushing of raw plant materials. There is therefore the need to ascertain the possible transfer of heavy metal into herbal medicines obtained from the various crushing procedures employed on the raw plant sample.

1.3 Objectives of the Study

1.3.1 General Objective

To determine levels of some heavy metals and assess the human health risk in selected medicinal plants used in the Ahafo Ano North Municipality.

1.3.2 Specific Objectives

i. To determine the levels of Cu, Pb, Zn, Cd and Mn, in *Azadirachta indica, Calotropis procera, Cassia alata, Theobroma cacao, and Vernonia amygdalina* medicinal plants using different grinding procedures.

ii. To determine the concentration of metals in soils and their physicochemical parameters. That is; soil pH, total dissolved solids (TDS), electrical conductivity and Organic matter content.

iii. To determine the extent of soil contamination by means of geo-accumulation index.

iv. To assess translocation factor TF, bioconcentration factor BCF and bio-accumulation coefficient BAC of soils.

v. To evaluate the human health risk assessment from hazard quotient, hazard index and carcinogenic risk.

1.4 Significance of Study

Most herbalists in Ghana depends on medicinal plants from the wild as raw materials for the preparation of their products as they do not cultivate the medicinal plants themselves. These medicinal plants are prone to absorb hazardous metals, accumulate and transfer them to animals and humans once ingested. Hazardous metals are toxic and can be found all over the place. This study sought to analyze some known medicinal plants predominantly used by the inhabitants of the area of research for the presence and levels of Cu, Pb, Zn, Cd and Mn, which have an immunological effect on humans. There is also the need to ascertain the hazardous elements profiles for medicinal plants in order to obtain a complete picture of the plant's constituents and educate the general public on the most ideal process of grinding raw plant parts before its varied applications. Atomic absorption spectrometer was used to determine the mean levels of hazardous metals in various medicinal plants.

1.5 Research Questions

The research questions that have inspired the conduct of this study are;

1. What are the physicochemical parameters of the soils in the area of study (pH, total dissolved solids TDS, electrical conductivity EC and organic matter content?
2. Do the study soils contain levels of hazardous metals which exceeds the permissible limits?
3. To what extent are the areas contaminated with the hazardous metals (geo-accumulation index)?
4. To what extent are the hazardous metals transferred to medicinal plants translocation factor TF, bio concentration factor BCF and bio-accumulation coefficient BAC
5. Have there been transfers of hazardous metals from stones, blenders or mortar and pestle that are employed to crush raw plant materials?

CHAPTER TWO

LITERATURE REVIEW

2.1 Medicinal Plants

Medicinal plants are of great significance to the health of humans and animals. The therapeutic properties of these plants lie in some chemical substances that produce a definite physiological action on the human body. These chemical substances are called phytochemicals. These are nonnutritive chemicals that have protective or disease preventive properties (Nadu, 2018). In this study, five medicinal plants were studied. These plants are *Azadirachta indica, Calotropis procera, Cassia alata, Theobroma cacao, and Vernonia amygdalina.* A brief description of each of the plant samples is given in the following sections.

2.1.1 Azadirachta indica *Linn* (Neem tree)

Neem plant is a fast-growing tree that can grow as long as 15 – 20 meters high. Its indigenous origin is India. The plant is cultivated in India and the tropical areas of the world such as Indonesia, Australia, West Africa and here in Ghana (Mondal & Chakraborty, 2016). The tree is variously known as 'Divine Tree' 'Heal All', 'Nature's Drugstore' 'Village Pharmacy' and 'Panacea for all diseases' in Indian traditional medicines. In East Africa it is known as Muarubaini (Swahili), which means the 'tree of 40', as it is supposed to cure 40 different diseases (Odoemelam, 2021). Its pinnate (compound) leaves are arranged in an alternate manner been 20 – 40 centimeter-long, with 20 – 30 dark green, serrated leaflets, each about 3 – 8 cm long. The terminal leaflet is usually not present. Their relatively short petioles are about 70 – 90 mm long. The stem bark is made of deep lines of breakage made by narrow opening in structure. Flowers are cream in color, has fragrant smell with bisexual flowers present on the same individual tree. Each inflorescence is 15 – 25 cm long. Each flower is about 1 cm in diameter with five petals, one style and ten stamens. Its ovary is syncarpous, superior, and three-celled with 1–2 ovules per cell (Ranjit, 2014) & (Njenga, 2017). The fruits are smooth, olive-like drupe, 1– 2.8 centimeter in diameter, which varies in shape from elongate oval to almost roundish. The fruit is yellow when ripped and very fibrous. The mesocarp is thick with dimensions of 0.2 - 0.5 centimeters. The hard-inner shell (endocarp) of the fruit which is white confines not often one to three, elongated seeds (kernels) having a brown seed coat. *Azadirachta indica* plant has a strong root system with a deep tap root and many lateral roots (Dubey & Kashyap, 2016).

Some of the anatomical disorders cured by the *Azadirachta indica* plant are arthritis, fever, syphilis, worm infestations, malaria and also purification and detoxification of the blood (Alonso-castro et al., 2012). It is effective when used as a contraceptive and in teeth cleansing (Njenga, 2017). The fruits and seeds of *Azadirachta indica* are the source of neem oil. The oil is essential for healthy hair, enhances liver function and stabilizes blood sugar levels. Leaves of the neem plant is substantial for the treatment of skin diseases like eczema and psoriasis (Dubey & Kashyap, 2016). This plant of interest has shown efficacy in destroying cancer cells and invigorating the body's immune system to protect it from later detrimental effect. Compounds extracted from the plant have shown impressive action against different class of human cancer cell that include liver, colon, lung, skin, oral, stomach, prostate and breast (Dubey & Kashyap, 2016). Nimbidin as one of the major components of *Azadirachta indica,* has been shown to own potent antiarthritic and anti-inflammatory activity. Nimbidin, is a compound extracted from the seeds as oils from the *Azadirachta indica* (Dubey & Kashyap, 2016). Nimbiden restrains the functions of macrophages and neutrophils pertained to inflammation. Antioxidant components in neem help to prevent brain damages. Low dosages of *Azadirachta indica* leaf extracts have sedative effects.

Compounds isolated from its leaves are key ingredient in non-pesticidal management, producing a natural alternative to artificial pesticides (Odoemelam, 2021). When seeds of neem are grounded into a powder and it is soaked overnight in water and sprayed onto crops, it functions as a repellent, an anti-feedant, and egg-laying deterrent, preserving and protecting the crop from adverse damage by harmful insects. The insects are made to starve and die out within some few days (Mondal & Chakraborty, 2016). Antipyretic activities: *Azadirachta indica* juice is indigenously used as antipyretic agent. It reduces body temperature and most often acts as antipyretic agent (Dubey & Kashyap, 2016).

Anti-gastric ulcer properties of neem plant: Characteristics of nimbidin, the bitter amorphous, neutral powder extracted from the oil expressed from the seed kernels of neem in animals and in humans with duodenal ulcer. The nimbidin reduced the incidence and severity of histamine induced duodenal ulcers in guinea pigs and fast tracking the healing of gastric ulcers induced by acetic acid in rats (Dubey & Kashyap, 2016). Liver protectant: Extracts of *Azadirachta indica* helps to protect the liver from damage, and by so doing helps to cleanse the blood. Neem leaves minimizes, chemically induced liver damage via stabilizing levels of serum marker enzymes and improving levels of antioxidants in the human system, like those found in vitamin C, vitamin E and carotenoids, which counteract free radicals and prevent damage

(Dubey & Kashyap, 2016). Anti-diabetics: With the extreme bitter properties of its extracts, *Azadirachta indica* has been one the basis of ayurvedic therapy for health implications caused by overeating sweets. Dysmenorrhea activities: The *Azadirachta* *indica* helps in curing severely painful menstruations. Juice produced from neem leaves and ginger juice mixed well and taken internally relieves one from painful menstruation. Plate 2.1 and Plate 2.2 are pictures of the leaves and fruits of *Azadirachta indica* respectively.

Plate 2.1.*Azadirachta indica leaves*   **Plate 2.2 *Azadirachta indica* fruits**

2.1.2 Cassia alata *Linn*

Cassia alata Linn belongs to the family Caesalpiniaceae. It traces its origin to many tropical countries like Africa, America, India, Indonesia and Brazil. It is an erect tropical herb that grows 2 - 4 m high predominantly grown in sunny and moist areas. It is a shrub with a very pungent smell (Nadu, 2018). The tree has a leather compounded leaves which are yellowish-green, broad, with 10 –14 leaflet pairs, the distal ones often larger and with a notched apex. The floral parts of it consisting of yellow flowers, long pedunculate, erect dense golden spike, crowded and overlapping each other. *Cassia alata* has a perfect and complete flower. Each flower contains 7 stamens, 2 of which are much longer and a pubescent ovary (Print et al., 2014). The fruits are usually 10 –16×1.5 cm tetragonal pod, brown when ripe and containing many diamond-shaped brown seeds (about 50 - 60 flattened, triangular seeds). An axis produces 4 - winged pods (that is legume liked) which buds at about 6 -12 inches away from each other (Length, 2014).

Cassia alata Linn is one of the promising medicinal plants used to treat various type of disease. The plant has great capabilities in traditional medicine. Pharmacologically, the leaves are used as a purgative, astringent , expectorant, and as a mouthwash (Length, 2014). Various extracts and different parts of *Cassia alata* have been reported to own many pharmacological activities such as; The leaf extracts of the plant have been investigated to have medicinal properties and used against ringworm, scabies, ulcers and other skin diseases such as pruritis, eczema and itching (Print et al., 2014). Anti-bacterial: Roots and leaf extracts of *Cassia alata* has great inhibition on the growth of many bacteria including; escherichia coli, Proteus mirabilis, Pseudomonas aeruginosa, Salmonella typhi, Staphylococcus aureus and Streptococcus Pyogenes (Nadu, 2018). Antifungal: Aqueous flower extract of *Cassia alata* is an antifungal agent for inhibitor of growth of aflatoxin producing fungi (aspergillusflavus), plant pathogenic fungi and human pathogenic fungi example candida albicans (Abubacker et al., 2008). Antioxidant**:** The *Cassia alata* leaves and flowers have very strong antioxidant activities. Wound healing: Wounds are the physical injuries that intend leads to an opening and rupturing of the skin. Suitable method for healing of the wound is crucial for the restoration of the interrupted functional status of the skin (Mishra et al., 2010). The extracts of leaves of *Cassia alata* were examined on excision wound model in Rats, the leaf extract fast tracked the wound healing ability by reducing the epithelialization period, obstruct high risk of sepsis and protraction of inflammatory phase (Print et al., 2014 ; Nadu, 2018). Both leaves and seeds extract had higher anti-plasmodial activity. All parts of this plant have been analyzed to exhibit one or more medicinal feature especially antimicrobial activities, hypoglycemic, analgesic, anti-inflammatory ,and anti-lipogenic activity (Print et al., 2014). The roots are used for the treatment of uterus disorders, and the pulverized leaves are used for skin infections. Leaves of cassia are used in preparation of herbal formulations such as herbal tea, herbal soaps, tincture, and herbal shampoos. The extracts of *Cassia alata* have been used in cosmetic formulation for dermatological skin care products (Khuda et al., 2010). Plate 2.3 is a picture of the aerial parts of *Cassia alata* plant.

Plate 2.3 Aerial parts of *Cassia alata Linn.*

2.1.3 Calotropis procera *Linn*

The plant *Calotropis procera* belongs to the family Apocynaceae. The plant is a xerophyte. The *Calotropis procera Linn* is an erect, highly branched and tall. The plant is a small tree and perennial shrub that grows to a height of 5.5 m with milky latex all through the plant. It originates from the tropical and subtropical Africa, Asia and sometimes common in the Middle East (Quazi et al., 2013). The plant can survive on different types of soils, from fine to coarse in texture, with varying levels of salinity (Jadhav, 2019). The bark of Calotropis is soft and corky. Its branches are stout, slightly tapering with fine appressed cottony pubescence especially on young (Meena et al., 2010)

Flower: The floral parts of the *Calotropis procera* consist of 5 small triangular off-white-colored sepals, 5 thick ovate petals (1cm x 1cm) which are usually white at the base and purple at the tips. It also consists of 5 purple tipped stamens, which encapsulates 5 white lobed stigmas. (Meena et al., 2010)

Fruit: The fruits appear as a green, spongy ovoid fruits, which is about 15 cm long by 10 cm wide. They split open to release their plumed that is the soft feathered, papery light brown seeds with a tuft of hairs on each seed (pappus) of white filaments up to 6.5 cm long on one side (Quazi et al., 2013) & (Ranjit, 2014).

Bark: The bark is separated from the wood in some diameter of 0.5 – 2.0 cm bearing rootlets with diameter ranging from 0.2 to 0.5 cm. Externally, it is whitish grey in color, wrinkled in the fresh condition, a lot of whitish latex exudes from lacerations or wounds in the bark (Bilal et al., 2020)

Leaf: The leaves occur on the plant in all seasons. They are a class of simple, opposite, sub-sessile, kind of thick, fleshy, having the texture of a leader about 10 - 15 cm long and 4.5 to 6 cm broad. It is generally wedge-shaped, often triangular with heart-shaped and sagittate at the base with tuff of short simple hairs on the upper side closer to the place of the attachment to the petiole (Quazi et al., 2013). The plant is popularly known by various vernacular names such as jealousy, jealousy cotton, swallow-wort, silk, flower-silk, milkweed and commonly referred to as ark (Khuda et al., 2010). They are commonly known as milk weeds because of the latex they produce. *Calotropis procera* plant is mentioned in ayurveda with important medicinal properties**.** According to literature, researches on the plant has shown to contain many biological active chemical groups including, cardenolides, steroids, tannins, glycosides, phenols, terpenoids, sugars, flavonoids, alkaloids and saponins. *Calotropis procera* as a medicinal plant has a considerable pharmacological effects such as antimicrobial anthelmintic, anti-hyperbilirubinemia ,leprosy treatment, ant inflammatory, analgesic and antipyretic (Jadhav, 2019), tumors, and piles, anticancer, antiangiogenic, immunological, antidiabetic, cardiovascular, hypolipidemic, gastroprotective, hepatic protective, renal protective, antidiarrheal, antioxidant, anticonvulsant, enhancement of wound healing, antifertility and smooth muscle relaxant effect, leucodermic (Ranjit, 2014)**,** (Bilal et al., 2020) and (Meena et al., 2010). Extracts of *Calotropis procera* leaves on glucose tolerance in glucose-induced hyperglycemic rats and mice showed a positive result indicating the potent nature of the extracts on harnessing the impact of the sugars. The leaves of *Calotropis procera* are used in several medicine of India and many parts of Africa to control blood sugar in patients suffering from diabetes mellitus (Ranjit, 2014).

Researches conducted by phyto-chemist has proven that its flowers possess digestive and tonic properties. On the contrary, the powdered root bark has been investigated to give relief in diarrhea and dysentery (Meena et al., 2010). The roots of the *Calotropis procera* have predominantly been used as a carminative in the treatment of indigestion. Again, the root bark and leaves of the plant are used by various tribes of Africa and central India as a curative medicine for jaundice (Quazi et. al., 2013). Plate 2.4 shows the aerial parts of the plant and Plate 2.5 is a structure of calotropin.

Plate 2.4 ***Calotropis procera***

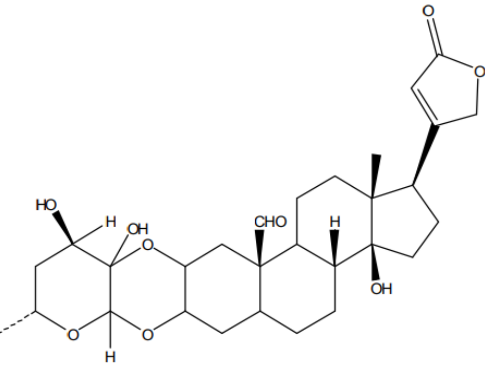

Plate 2.5.Calotropin

2.1.4 *Vernonia amygdalina*

Vernonia amygdalina as a medicinal plant is a perennial shrub often referred to as bitter leaf plant. The name bitter leaf was ascribed to the plant due to the bitter taste of its leaves. The amygdalina plant stem from the Asteraceae (compositae) family (Iruoghene et al., 2023).The plant is a multipurpose and rapid regenerating soft wooded usually present as a shrub of about 2 – 5 m height. In some few instances has the plant been reported to be as tall as 7m height. The stem of *Vernonia amygdalina* has a rough bark with dense black straits. The leaves of amygdalina plant are colored dark green and elliptic with a characteristic smell and bitter taste. The petiolate leaves of the plant are around 6 mm in diameter (Ogidi et al., 2019). Every part of the plant has an identified pharmacologically usefulness. Both the roots and leaves are used in herbal medicine to treat fever, hiccups, kidney disease and stomach discomfort and many more. When the bark of the stem and root are striped off it is used as chew-sticks for oral hygiene, and for the management of some dental complications in Ghana. The leaves as well are used to prepare soup and are also reportedly consumed by goats in most parts of the country. (Ogidi et al., 2019). Antihelmitic, antimalarial and antitumorigenic characteristics has consistently been reported for extracts from this plant. Other researches conducted have demonstrated hypoglycaemic and hypolipidaemic potency of the leaf extract in experimental animals (Ojimelukwe & Amaechi, 2019).

Other than animals, many people in Ghana for that matter Africa especially patients who were less educated with little or middle income also preferred to use this plant for many medicinal purposes, due to cultural and economic reasons. In as much as the plant can be applied singly as a herbal ingredient its extracts have also been integrated as an important component in traditional polyherbal formulations to treat various diseases (Yeap et al., 2010). Current scientific research in the last few decades about the plant has scrutinized these assertion and found that extracts from the plant have numerous phyto-therapeutic properties (Brima, 2022).

African traditional herbal medicine practitioners have consistently used the plant as a laxative, digestive tonic, appetizer, febrifuge and treatment of wounds. In some part of Malawi and Uganda, *Vernonia amygdalina* is used by traditional birth attendants to facilitate the expulsion of the placenta, after birth, aid post-partum uterine contraction, induce lactation and control post-partum hemorrhage (Yeap et al., 2010).

Bitter leaf in similar manner is credited to have benefits for women's reproductive health as it helps to regulate menstrual cycles and reduce symptoms of premenstrual syndrome (Iruoghene et al., 2023). Plate 2.6 is a picture of dried leaves of bitter leaves and Plate 2.7 is a structure of the plant as a whole.

Plate 2.6 Leaves of *Vernonia amygdalina*

Plate 2.7 *Vernonia amygdalina* plant

Table 2.1 Traditional uses of *Vernonia amygdalina*

Country	Preparation	Ailments
Ethiopia	Leaves (not root)	Stomach disorder, skin wound, diarrhea, scabies, hepatitis, ascarasis, tonsillitis, fever, mastitis, tapeworm and worms infection.
	Leaves and root	Stomach ache (worm expulsion)
Democratic Republic of Congo	Leaves and root bark	Diarrhea, dysentery, gastroenteritis, malaria, hepatitis, worms infection
Ghana	Leaves decoction	Malaria, fever, constipation, abortifacient, stomach sores, ulcer, pain, upper respiratory tract infections and dermatitis.
Gabon	Leaves juice	Tinea
Guinea	Leaves decoction	Cough
Nigeria (Hausa tribe of northern)	Leaves, Root and twig	Stomachache, gastrointestinal troubles, oral hygiene, itches, parasitic infection, ringworm, typhoid fever, headache, diabetes, constipation, pile (haemorrhoids) and reduces aflatoxin contamination of storage cobs.
Cameroon	Leaves	Malaria, helminthosis
	Maceration of leaves drink many times for 1 day.	Intestinal diseases
South Africa	Root	Schistosomiasis, infertility, amenorrhoea.
West Africa	Tea	Diuretic, skin infection, constipation, diabetes, metabolic diseases associated with liver
Senegal		Female insterility
Guruve, Zimbabwe	Root	Sexually transmitted disease
India	Leaves	Diabetes
Uganda	Stem, Root	HIV (reduce fever, rash, pain, cough, stomachache) Measles, amoebiasis, influenza and mastitis infection.
	Leaves	Convulsions, cough, painful uterus, inducing uterine contraction, management of retained placenta and post partum bleeding, induced abortion, irregular or painful menstruation, infertility, colic pains bacterial and fungal infections
	Root/Leaves	
Rwanda	Leaves, Fruit	Diarrhea, gastroenteritis, hepatitis, dysentery, malaria, worms infection.
Tanzania	Leaves	Snake bite (chew), fever, stomachache, as appetizer
	Root	Trematode
Kenya	Leaves, Root	"Wuoyo", "Mbaha", diarrhoea, "Sihoho" stomachache, bloat, east coast fever, footrot, trematode

(Ogidi et al., 2019), (Iruoghene et al., 2023), (Ojimelukwe & Amaechi, 2019), (Del et al., 2015) and (Yeap et al., 2010).

2.1.5 *Theobroma cacao Linn*

Theobroma cacao usually referred to as cocoa tree is a small evergreen tree in the family Sterculiaceae. The plant is about 4 – 8 m or 15 – 26 feet tall. Cocoa is known to be a native to the deep tropical region of America (Ishaq & Jafri, 2017). The flowers of the *Theobroma cacao* are produced in clusters directly on the trunk and older branches; they are small, about 1–2 cm diameter, with pink calyx. Flowers of most plants are pollinated by bees (Hymenoptera) or butterflies/moths (Lepidoptera), however, the flowers of *Theobroma cacao* are pollinated by tiny flies called forcipomyia midges (Ishaq & Jafri, 2017).

The fruits of the plant are commonly called a cacao pods, it is ovoid, about 15 – 30 cm long and 8 – 10 cm wide. They usually green when unripe but becomes yellow to orange when ripen, it has an average weight of about 500g when ripe. Each pod contains 20 to 60 seeds, usually called "beans". The beans are implanted in a white pulp. Each seed of cocoa contains an appreciable amount of fat (about 40 – 50%) as cocoa butter. Theobromine is the most noted active constituent in cocoa, a compound similar to caffeine (Ishaq & Jafri, 2017). There are several foods and cosmetics in which cocoa is an ingredient (Gyamfi et al., 2023). The seeds of the *Theobroma cacao* are noted to have an intense bitter taste, and that it must be fermented to develop the flavor. Cocoa is in itself a class of beverage.

Cocoa cannot be an exception looking at the nations resources, it could conceivably in Ghana become a key factor for measuring the Government's commitment to many of her rural inhabitants (Amankwah, 2013). The Government of the country become responsible in the management of the cocoa market, fixation of price and the execution of some other fringe benefits as bonuses coupled with pest and disease control practices (mass spraying). The price and fringe benefit are used as motivating factors which could influence both the quantity produced and quality of the beans.

It is believed that in 1857, the Basel missionaries first introduced cocoa into Ghana the then Gold Coast and planted them at Aburi in the Eastern Region (Amankwah, 2013). Howbeit, most of these plants could not survive with time. These cocoas planted did not result in the spread of cocoa cultivation in Ghana until Tetteh Quarshie, a native of Osu in Greater Accra Region, who had journeyed to Fernando Po in Equatorial Guinea and worked there as a blacksmith. He returned in 1879 with Amelonado cocoa pods and established a farm at Akwapim - Mampong in the Eastern Region as reported by Amankwah in 2013. The then Ghanaian farmer's procured pods from his farm to plant and as a result cultivation extended from the Akwapim – Mampong area to other parts of the Eastern Region. These trees became the parent trees for Ghana's cocoa industry. From Akwapim – Mampong, cocoa farming outspread to Ashanti, Brong and Ahafo, Central and Western Regions. By 1939, cocoa accounted for about 80% of the country 's total foreign exchange. The country by then continued to be the leading producer of cocoa, producing about 570,000 tons yearly in the mid-1960s (Amankwah, 2013).

Today, Ghana 's cocoa beans is slated to be of good quality which is based not only on the issue of taste but also due to low pesticide use compared with what pertains to other big plantations in other producing countries elsewhere in the world (Amankwah, 2013). Most Ghanaian farmers are small scale producers and more often cannot afford many pesticides; they therefore turn to apply traditional methods of pest control which includes; careful weeding around the plant, pruning, and waste disposal. Notwithstanding, the Ghana COCOBOARD keep check on the introduction of new pesticides into the system so as to control any initiation of possible crop contaminants (Amankwah, 2013).

Cocoa on itself stands as the main drive for the nation 's economy. Cocoa is a cash crop and vital export for producing countries and in contrast a major import for consuming countries which more often than not have no suitable weather pattern for cocoa production (Amankwah, 2013). In the 20th century, the plant in question was set as Ghana's principal means of foreign exchange earnings. The plant understudy truly plays a greater role in Ghana's economy and renders employment to many small-scale farmers.

Theobroma cacao as a medicinal plant has a considerable pharmacological effects such as anti-cancer activity; an evaluation on polyphenols from cocoa, coffee and tea resulted in anti-cancer activity of these beverages (Ishaq & Jafri, 2017).

Antioxidant Activity: from an in vitro and in vivo investigation conducted to check the antioxidant activity of *Theobroma cacao* plant. The investigation revealed that the flavanols from cocoa extracts have a high antioxidant activity (Yembeau et al., 2018) & (Ishaq & Jafri, 2017).

Effects on Cardiovascular Health: findings from other researches has revealed that the consumption of foods rich in polyphenolic compounds, especially cocoa, may have cardio protective effects (Ishaq & Jafri, 2017). A crossover study conducted on the plant by many phyto-chemist and researchers has shown that the plant also has the following health implications on humans. anti-fatigue syndrome activity, anti-cough activity, anti-diabetic activity, anti-hypertensive activity, anti-inflammatory activity, anti-influenza activity, anti-malarial activity (Yembeau et al., 2018). Similarly, there have been studies suggesting that the regular or occasional consumption of cocoa-rich compounds has beneficial effects on blood pressure, effects on brain perfusions, effects on body's cholesterol level, effects on platelet activities, effects on humoral immunity, insulin resistance, vascular damage, and oxidative stress (Ishaq & Jafri, 2017). Plate 2.8 shows the seeds of cocoa in its pod and Plate 2.9 is a structure of theobromine.

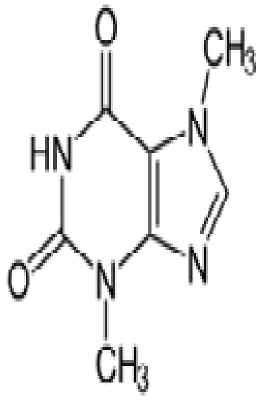

Plate 2.8 ***Theobroma cacao*** **seeds** **Plate 2.9 Theobromine**

2.2 The Selected Heavy Metals

The term heavy metal refers to any metallic chemical element that has a relatively high density and is toxic or poisonous even at low concentration. Heavy metals are potential environmental contaminants with the capability of causing human health problems if present to excess in the food we eat (Brhane & Dargo, 2014).

Heavy metals are natural constituents of the Earth's crust. Human activities have drastically altered the balance and biochemical and geochemical cycles of some heavy metals. Therefore, the concentration of heavy metals in soils has been an issue of great interest in the past few years not only to ecologists, biologists and farmers but also environmentalists. Heavy metals, which are potentially harmful to human health, persist in soils for a very long time. In addition, according to soil parameters they may enter the food chain in significantly elevated amounts (Ojo et al., 2015)

Adsorption by roots is the main route of trace elements to plants but other tissues have been perceived to absorb trace elements. Transport of ions within plant tissue and organs involves movement in phloem and xylem, storage, accumulation and immobilization. The translocation and accumulation patterns of trace elements vary greatly for each element, the kind of plant and the growth season. Elements such as copper and zinc appears to be distributed more evenly throughout the plant (Page, T. (2017). High levels of contamination in medicinal plant soils can affect both the plant and its production. The health of individuals that consume or ingest products from these plants, could also be negatively impacted (Abdulhamid et al., 2015). The impact could be more severe if pollutants are hazardous substances, such as heavy metals. Metals such as copper (Cu), lead (Pb), manganese(Mn), cadmium (Cd) and zinc (Zn) are common contaminants encountered in the soil environments (Takarina & Pin, 2017).

2.2.1 Sources of heavy metals contamination in Soils and medicinal plants

Heavy metal depositions springs from a wide range of sources such as vehicular emissions, small-scale industries including (battery production, metal products, metal smelting and cable coating industries), suspended road dust and diesel generator sets. Coal combustion is equally a significant source of contamination. Other sources of heavy metals in field locations in urban area incorporate irrigation with water contaminated by sewage and industrial effluent leading to contaminated soils and contaminated medicinal plants. Other sources can include excess or unregulated application of pesticides, fungicides, fertilizers and sewage sludge (Brhane & Dargo, 2014). Heavy metals may be present as a deposit on the surface of medicinal plants, or may be taken up by the roots and incorporated into the plant tissue and the shoot system as well. These can be important contributors to the contamination found in medicinal plants. According to Brhane and Dargo, (2014) it is well known that plants take up metals by absorbing them from contaminated soils as well as from deposits on parts of the plants exposed to the air from polluted environments. The ingestion of these medicinal plants is an obvious means of exposure to heavy metals, not only for the fact that many metals are natural components of foodstuffs but also because of environmental and processing contaminations.

2.2.2 Lead Pb

Lead as an element is a metal belonging to group IV and period 6 of the periodic table with atomic number 82. It has a relative atomic mass of 207.2,with density 11.4 gcm^{-3}, and having melting point and boiling points 327.4 ^{o}C and 1725 ^{o}C respectively (Wuana & Okieimen, 2011). Lead is said to occur naturally, it occurs as a bluish gray metal usually found as a mineral combined with other elements, such as Sulphur (in the form of PbS and $PbSO_4$ or oxygen in the form of $PbCO_3$. Its occurrence ranges from 10 to 30 $mgkg^{-1}$ in the earth's crust (Wuana & Okieimen, 2011). Lead exists as a soft, dense, and ductile metal. It is a natural environmental pollutant, however its ubiquitous occurrence in the environment results to a greater extent from anthropogenic activities including illegal mining and smelting, soldering, battery manufacturing, ammunition and particularly the use of lead in paint and petrol sometimes past (Brhane and Dargo, 2014). Most of the lead used predominantly across the globe goes into the manufacture of lead storage batteries. The toxic repercussions of hazardous metals, particularly mercury, arsenic, cadmium and lead, have been broadly studied (Rahimi et al., 2010).

Lead in itself is a toxic metal even when it is present in low concentration. It causes health hazards since it is not biodegradable and it may cause kidney damage. Lead Pb accumulates in the tissues of animals and humans which may eventually lead to poisoning popularly known as plumbism or in severe cases death. Exposure to lead could bring about many adverse health effects, comprising: hypertension, gastrointestinal effects, anemia, nephropathy, decreased growth, immune and nervous systems dysfunctions, some behavioral/cognitive disabilities, hearing loss and effects on reproduction (Al Zabadi et al., 2018). Studies on lead (Pb) has proven that the element is known to induce reduced cognitive development and intellectual performance in children and increased blood pressure and cardiovascular disease in adults (Rahimi et al., 2010). In general, young children and infants are particularly in danger to lead poisoning. The exposure of children to lead leads to a high risk for impaired development, lower IQ, shortened attention span, hyperactivity, and mental deterioration. Studies has lay to bear that children under the ages of six are at a more significant risk. Adults exposed to lead may often times experience decreased reaction time, loss of memory, nausea, insomnia, anorexia, and weakness of the joints when exposed to lead (Wuana & Okieimen, 2011 ; Dubey & Kashyap, 2016).

Exposure to lead can cause a wide range of biological impacts depending on the level and exposure duration. Many consequences occur over a broad range of doses, with infants more affected (Singare & Talpade, 2013). The metal has no known essential biological importance in the human body, it can merely be toxic after uptake from food, air, or water. Lead is specifically a dangerous substance, as it can accumulate in individual organisms, and can also accumulate in entire food chains. Any marginal increase in levels of this metal in soils and medicinal plants may negatively affect the health of both animal and human consumers in the long term because Pb is in itself toxic to the organism, even if it is absorbed in small amounts (Miholova et al., 2015). This apparently justifies the increased positive impacts of natural resources monitoring and protection from the combined efforts of responsible government institutions such as the environmental protection agency (EPA) given the mandate to control human activities that leads to the releases of lead into the environment especially the water resources from main sources such as illegal mining, human and animal excreta, agrochemicals containing phosphatic fertilizers (Ameyaw et al., 2012).

Lead metal forms alloys with other metals including antimony as applied in storage batteries, calcium (Ca) and tin (Sn) used in the maintenance-free storage batteries), silver (Ag) for solder and anodes, strontium (Sr) and Sn which is also used as anodes in electrowinning processes, tellurium (Te) used in making pipe and sheet in chemical installations and nuclear shielding, Sn for solders and for sleeve bearings, printing, and high-detail castings (Wuana & Okieimen, 2011). Ionic lead, Pb (II), lead oxides and hydroxides, and lead metal oxyanion complexes are the extensive forms of lead Pb that are released into the soil, groundwater, surface waters and finally to medicinal plants. The very most stable forms of lead are Pb (II) and lead-hydroxy complexes.

2.2.3 Cadmium Cd

Cadmium is positioned at the end of the second row of transition elements with atomic number 48, with atomic mass of 112.4, and density 8.65 g cm^{-3}, cadmium has melting point and boiling points of 320.9 ◦C and 765 ◦C respectively. (Wuana & Okieimen, 2011). When cadmium is present in compound forms, it occurs as the divalent Cd (II) ion. The element cadmium is one of the most poisonous metals posing serious risks to human health. It so because its excretion from the body is very small with a half-life in the range of 20 – 40 years, for this reason, small concentrations of it can probably lead to its accumulation in the body (Qasemi et al., 2019). The World Health Organization (WHO) has classified ten chemical elements as an important public health concern and it includes these four heavy metals cadmium, arsenic, lead, and mercury. The International Agency for Research on Cancer (IARC) classifies cadmium in Group 1: meaning it is carcinogenic to humans and the US Environmental Protection Agency (US

EPA) has also examined that cadmium is one probable human carcinogen via inhalation (Qasemi et al., 2019).

Cadmium has no known essential biological functions to humans. It is a toxic and nonessential trace element to all other living organisms including human beings, it is widely distributed in the earth's crust at low concentrations (< 1 mg/kg), but there is the possibility of an increase to higher concentrations close to metal mining and smelting activities. This is possible due to the existence of cadmium up to 300 mg/l in phosphate fertilizers (Qasemi et al., 2019).

Cadmium is well positioned directly beneath the element zinc Zn in the periodic table and has a chemical similarity to that of zinc Zn, which of course is an essential micronutrient for plants and animals. This may partially account for cadmiums toxicity. The fact that zinc Zn is an essential trace element, its substitution by cadmium Cd may cause the malfunctioning of metabolic processes (Wuana & Okieimen, 2011). Cadmium can find its way into the human body through the ingestion food and water, smoking and occupational exposure through inhalation and possibly through dermal contact. For many consumers from a particular inhabitant, food and water is the most crucial exposure route (Solomon et al., 2022). The intake of cadmium-contaminated products over a long period can result in the build-up of cadmium in different vital organs and tissues including the liver, kidneys, immune system, bone, and reproductive organs, but the most affected part being the kidneys. Cadmium is a potent cause of several kinds of cancers and cardio-vascular diseases (Qasemi et al., 2019). The application of cosmetics on the skin is one conceivable avenue of exposure to Cadmium (Cd), which can result in many detrimental effects, including cancers. Cadmium toxicity has also been linked with cellular apoptosis, endocrine dysfunction and damage of the DNA (Gyamfi et al., 2023). The health effects of cadmium exposure are exacerbated due to the inability of the human body to excrete cadmium. Short-term exposure to inhalation of cadmium can cause severe impairments to the lungs and respiratory irritation while its ingestion in higher dose can result in stomach irritation leading to vomiting and diarrhea. Long-term exposure to cadmium Cd leads to its deposition in bones and lungs. And as such, cadmium exposure can cause bone and lung damage. Additional researches has proven that cadmium can cause testicular degeneration and a potential risk factor for prostate cancer (Wuana & Okieimen, 2011).

The major significant application of cadmium is its usage for NiCad cells, that is Ni/Cd batteries which are rechargeable or secondary power sources demonstrating a high output, long life, low maintenance, and has high tolerance to physical and electrical stress. Electroplating with cadmium provides a very good corrosion resistance coating to vessels and other vehicles, specifically in high-stress environments such as marine and aerospace. Cadmium as a metal has other applications as pigments, stabilizers for polyvinyl chloride (PVC), in making of alloys and electronic components (Wuana & Okieimen, 2011). Although Cd is not an essential element for plants, it is extensively absorbed by the root system and is accumulated in soil organisms at high levels. This metal can easily penetrate the xylem of the root system via the apoplastic and/or symplastic pathway (Rezapour et al., 2023).

Medicinal plants and other edible crops can easily accumulate toxic levels of cadmium when cultivated on polluted soils to add them further in the trophic chain from soil to plant and then to animal) (Wuana & Okieimen, 2011). The process of cadmium uptake and accumulation in different plants incorporates both soil and plant factors. Some of which important factors include soil physicochemical parameters (example; total dissolved solids, soil electrical conductivity, pH, soil organic matter, and texture), plant species, interaction of the metal with other elements within plant organs, and chiefly the extent of anthropogenic activities and their duration (Rezapour et al., 2023).

2.2.4 Zinc Zn

Zinc is positioned in period 4 and in group IIB of the period table. Zinc is another transition metal with atomic number 30, with atomic mass of 65.4, and density 7.14 g cm^{-3}, zinc has melting point and boiling points of 419.5 °C and 906 °C respectively. Zinc occurs naturally in the earth crust around 70 mg/kg in crustal rocks (Wuana & Okieimen, 2011). The amounts of this metal keep increasing unnaturally due to anthropogenic activities. Majority of the soils zinc content is added to the environment and subsequently to medicinal plants in the cause of industrial activities, such as mining, waste combustion, coal combustion and steel processing (Wuana & Okieimen, 2011). Many foodstuffs and medicines contain certain levels of zinc. Potable water also contains certain levels of zinc, which may be slightly higher when its storage containers is made from metal (Ogbonna et al., 2013). Toxic waste from industrial sources or sites may cause the increased concentrations of zinc in medicinal plants or in soils to reach levels that can cause health problems. Zinc is classified as a trace element that is indispensable for human health. The deficiency of zinc can cause birth defects. Some medicinal plants can accumulate zinc (Zn) in their tissues, when they are situated in zinc contaminated environments (Wuana & Okieimen, 2011). When the element zinc enters the tissues of these medicinal plants, it is able to biomagnify up the food chain. Water - soluble zinc that is located in soils can contaminate groundwater as well as medicinal plants. Plants more often than not have a zinc uptake that their systems cannot handle, due to the accumulation of zinc in soils. Eventually, the metal zinc can interrupt the activity in soils, as it negatively impacts the activity of microorganisms and earthworms, therefore retarding the breakdown of organic matter (Wuana & Okieimen, 2011). Zinc is relatively non-toxic. Zinc deficiency is characterized by recurrent infections, lack of immunity and poor growth. Growth retardation, skin changes, poor appetite and mental lethargy are some of the manifestations of chronically zinc-deficient human subjects (Fathabad et al., 2015) & (Wuana & Okieimen, 2011). However, the lack of zinc can result from inadequate dietary impaired absorption, excessive excretion or inherited defects in zinc metabolism (Al Zabadi et al., 2018). Zinc is primarily needed for the growth and multiplication of cells, that is its why it is employed as an enzyme responsible for DNA and RNA synthesis, responsible for skin integrity, bone metabolism and functioning of taste and eyesight. It forms one of the major components of many enzymes and insulin. Zinc deficiency causes weight loss, excessive bleeding, boils, permanent wounds and skin disease (Lokhande et al., 2010).

2.2.5 Copper Cu

Copper is positioned in period 4 and in group IB of the period table. copper is another transition metal with atomic number 29, with atomic mass of 63.5, and density 8.96 g cm^{-3}, copper has melting point and boiling points of 1083 ^{o}C and 2595 ^{o}C respectively. The mean density of the metal is 8.1×10^{3} kgm^{-3} and its concentrations in the crustal rocks is 55 $mgkg^{-1}$, respectively (Wuana & Okieimen, 2011). Literatures on the metal under study has shown that copper is the third most used metal in the world. Copper is one of the essential micronutrients required in the growth of both plants and animals. In humans, copper is required in the production of blood hemoglobin. In plants, copper (Cu) is exceptionally important in seed production, plant disease resistance, and regulation of water. Copper is indeed an imperative element in animals and humans, but in high doses it can cause anemia, damages to the liver and kidney and stomach and intestinal irritation.

Copper unlike other metals, do not easily magnified in the body or bioaccumulated in the food chain (Wuana & Okieimen, 2011).

In soils, copper extensively complexes to the organic matter components suggesting that only a small fraction of copper will be found in the soil solution as ionic copper, Cu (II). The solubility of copper drastically increases at a pH around 5.5 which is quite close to the ideal farmland pH ranging from 6.0 – 6.5 chain (Wuana & Okieimen, 2011). Copper, manganese and zinc are known to be essential and may enter the medicinal plants from soil via mineralization by plants or environmental contamination with metal-based pesticides. These metals mentioned are essential micronutrients if consumed in acceptable amounts, however they might become toxic when consumed in excess. The adult human body is expected to contains about 1.5 – 2 mg/l of copper (Wuana & Okieimen, 2011).

2.2.6 Manganese Mn

The element manganese (Mn) is a transition metal which belongs to period 4 and group 7B of the periodic table. Manganese has atomic number 25, with atomic weight of 54.94, having a density of 7.26 gcm^{-3}, and melting point and boiling point of 1244°C and 2095°C respectively. (Wuana & Okieimen, 2011). Manganese is a hard metal and it is extremely brittle. Manganese is highly reactive when it is in the pure form. It burns in oxygen readily when it is in the powder form. It is able to react with water and dissolves in acids. Manganese is one major constituent of low-cost stainless-steel formulations and extensively used aluminum alloys. Manganese dioxide (MnO_2) is commonly used as a catalyst. Manganese is utilized to decolorize glass and make violet colored glass. Potassium permanganate ($KMnO_4$) is a strong oxidizer and it is used as a disinfectant. Manganese oxide (MnO) is applied in the production of fertilizers and ceramics.

Manganese carbonate ($MnCO_3$) is employed as the starting material for making other compounds of manganese (*Manganese ; CASRN 7439-96-5*, 1995). The occurrence of the manganese in the soils is inexhaustive, where it occurs mainly as oxides and hydroxides. Manganese is one of the essential micronutrients required in the growth of both plants and animals. Manganese is equally needed for the normal synthesis and secretion of insulin by pancreatic cells. Treatment with manganese (Mn) has been investigated to improve glucose tolerance under conditions of dietary stress (Konieczynski et al., 2022). Manganese is one ubiquitous trace element required for normal growth and cell development in all animal species. It is a critical component in dozens of proteins and enzymes (Konieczynski et al., 2022). In humans, manganese is found mostly in the bones but also in the liver, kidneys and the brain. In the human brain the manganese is tied up to manganese metalloproteins, primarily glutamine synthetase in astrocytes. Several human health conditions have been associated with both deficiency and excess intake of manganese. Consequently, any quantitative evaluation on manganese must take into accounts aspects of both the essentiality and toxicity of manganese. Some of the sources of manganese contamination in the environment include; welding, fuel addition, ferromanganese production etc. Some of the effects of manganese on human health include; inhalation or contact damage to the nervous system (Singh et al., 2011). The absorption of manganese by humans mainly takes place through food such as tea and herbs. Manganese Mn effects occur mainly in the respiratory tract and in the brain. Some common symptoms of manganese contamination are hallucinations, forgetfulness, dullness, weak muscles, headaches, insomnia, schizophrenia and nerve damage. Manganese can also cause Parkinson, lung embolism and bronchitis. Excess exposure of males to manganese for a longer period of time may render them becoming impotent. (Chase, 2017).

2.3 Physicochemical Parameters

2.3.1 Soil pH

The pH of a soil has a significant consequence on metal dynamics because it has a direct influence on the adsorption and precipitation, which are the fundamental mechanisms of metal retention in soils. The solubility of cationic forms of metal in the soil solution increases as the pH decreases and thereby become more easily available to plants (Abdulhamid et al., 2015). Soil pH exceedingly influences the concentration and availability of metals in the soil via several chemical and biological processes. Heavy metal mobility decreases with increasing soil pH, and because of that soil sites with low pH had relatively high concentration of the selected heavy metals (Abdulhamid et al., 2015). Soil pH influences the adsorption capacity of soil particles for metal ions. Soil particles, specifically clay minerals and organic matter, has negative charges on their surfaces. The pH of a given soil solution have an impact on the net charge of both soil particles and metal ions (Reth et al., 2014). In acidic soils, where the pH is low, the levels of hydrogen ions (H^+) increases, leading to a greater positive charge on soil particles. This increased positive charge can elevate the adsorption of metal ions onto soil particles, reducing their concentration in the soil solution. Conversely, in alkaline soils, the abundance of hydroxyl ions (OH^-) can grapple with metal ions for adsorption sites, potentially decreasing metal adsorption and increasing their concentration in the soil solution (Neina, 2019). Soil pH directly influences the solubility of metal compounds. In acidic soils (low pH), metals such as manganese (Mn) tend to be more soluble. This increased solubility can lead to higher concentrations of these metals in the soil solution, making them more available for plant uptake and potentially increasing the risk of toxicity. On the other hand, in alkaline soils (high pH), metals like zinc (Zn) and copper (Cu) may become more soluble, leading to increased concentrations of these metals in the soil solution (Heiniger et al., 2003). In general, knowledge about the relationship between soil pH and metal concentration is imperative for managing soil quality, environmental pollution, and agricultural productivity (Abdulhamid et al., 2015).

2.3.2 Soil Electrical Conductivity (EC)

Electrical conductivity measures the ability of a solution (in this case, soil solution) to conduct electricity, which is influenced by the concentration of ions dissolved in the solution. Metals in soil occurs in various ionic forms, and their concentration affects the overall ion concentration in the soil solution (Corwin & Lesch, 2005). Therefore, high concentrations of metals in soil can increase the electrical conductivity of the soil solution. This implies that, soils with high metal concentrations have the potency to exhibit elevated electrical conductivity due to the presence of these metal-containing salts. Measurement of the soils electrical conductivity is influenced strongly by several soil physical and chemical parameters. Some of which properties includes soil salinity, soil water content, and the soils bulk density (Corwin & Lesch, 2005). Soil electrical conductivity is a make of two compositions: (i) the impart of the soils solid particles to exchangeable cations and (ii) the influence of the soil solution (Heiniger et al., 2003). The total salt concentration in the soil solution is referred to as soil salinity. The buildup of salinity in the soil root zone can negatively affect the growth and yields of plants making it difficult for plants to obtain water, interfering the nutritional stability of plants or causing toxicity by a specific ion and thereby affecting physical properties of soil (Corwin & Yemoto, 2019). To a larger extent, soil electrical conductivity is not a direct measure of soil metal concentration, it can serve as an indicator of the presence and concentration of ions, including metals, in the soil solution. Examining soil electrical conductivity alongside other soil physicochemical parameters can provide valuable information about soil salinity, ion availability, and potential metal contamination (Corwin & Yemoto, 2019).

2.3.3 Soil Organic Matter

Soil organic matter content is a comparatively stable, combined soil property that reflects long-term land use and is a significant indicator of soil quality. The continuous sustenance of ideal soil physical conditions is an important component of soil fertility management. The defective soil structural condition and breakdown of soil aggregates more often than not restricts crop root growth and hence the efficient exploration of the soil profile for water and nutrients (Haynes & Naidu, 1998). Soil organic matter is one crucial contributor to biogeochemical cycles of the major nutrient elements. The concentration and quality of soil organic matter represents the balance of primary productivity and decomposition. Soil organic matter is therefore a sensitive and integrated measure of change in ecosystem function (Burke & Schimel, 2014).

Organic matter contains different functional groups, which may include carboxyl (-COOH), hydroxyl (-OH), and amino (-NH_2) groups, which can act as binding sites for metal ions. These functional groups form complexes with these metal ions through varied processes such as chelation, adsorption, and complexation (Abdulhamid et al., 2015). As a result, organic matter can reduce the mobility and bioavailability of metals by immobilizing them in the soil matrix. The presence of organic matter provides energy and carbon sources for microorganisms, and as a result of that impacting metal cycling and bioavailability in soils. All inclusive, soil organic matter content exerts a significant influence on the concentration, mobility, and bioavailability of metals in soils, impacting environmental quality, agricultural productivity, and ecosystem health (Ogbonna et al., 2013). Soil organic matter content could be increased through various means example humic molecules and polysaccharides are added which are intimately involved in binding soil aggregates together in other to enhance soil aggregate stability. Furthermore, application of lime and fertilizers to soil will greatly impact the chemical composition of soil solution. The pH and ionic composition of soil solution can massively affect the flocculation and dispersion of soil particles (Haynes & Naidu, 1998).

2.3.4 Total Dissolved Solids (TDS)

Total Dissolved Solids corresponds to the total concentration of dissolved ions in the soil solution, including metal ions (Rhoades, 1996). Increased total dissolved solid levels indicate a higher concentration of dissolved salts in the soil. High TDS levels can contribute to leaching of metals from the soil. Metal ions dissolved in the soil solution can be carried with water as it percolates through the soil profile. With higher total dissolved solids, there is a greater tendency of metal ions being dissolved and becoming more mobile in the soil solution. This increased solubility can result to higher concentrations of metals in the soil (Rhoades, 1996). Changes in total dissolved solids can make adjustment to soil pH and the availability of organic matter that can complex with metals. These changes can affect the solubility, mobility, and toxicity of metals in the soil. For example, under high total dissolved solids conditions, changes in pH may favor the formation of more soluble metal species, increasing their concentration in the soil solution (Ogbonna et al., 2013).

2.4 Assessment of metals/heavy metals in soils and plants

The assessment of metals/heavy metals in soils and plants involves analyzing the concentration of these elements in the selected samples. This is done to understand the potential risks they pose to human health and the ecosystem. Metals and heavy metals are naturally occurring elements that can be found in the environment. While some metals are essential for human health, such as iron and zinc, others can be toxic and harmful, such as lead and cadmium (Wuana & Okieimen, 2011). Therefore, it is important to assess the levels of these metals in soils and plants to determine if they pose a risk to human health or the environment.

2.5 Grinding procedure

The grinding process helps to break down the plant material and expose the internal structures, making it easier to analyze. Grinding plant samples with a mortar and pestle made of wood is a method used to prepare plant materials for analysis. The mortar, which is often a hard wood, is used to hold the plant material, while the pestle, which is often a heavy wooden rod, is used to crush and grind the plant material into a fine powder (Sobhan et al., 2022) . This powder can then be analyzed for various substances, such as metals or other contaminants.

Grinding plant samples with a stone is a traditional method used to prepare plant materials for analysis. The stone, which is often a hard rock or mineral, is used to crush and grind the plant material into a fine powder (Adella, 2017). This powder can then be analyzed for various substances, such as metals or other contaminants. The use of a clean and hard stone is important to avoid contamination of the sample and ensure that the grinding process is effective.   Grinding plant samples with a blender is a method used to prepare plant materials for analysis. The blender, which is often a high-speed mixing device, is used to crush and grind the plant material into a fine powder. The use of a clean blender and hard blade is important to avoid contamination of the sample and ensure that the grinding process is effective (Owen et al., 2019).

CHAPTER THREE

MATERIALS AND METHODOLOGY

3.1 Study Area

The study was conducted at Tepa, the largest community and the municipal capital of the Ahafo – Ano North Municipal within Ashanti Region ($7^0$0'N, $2^0$10'W) situated at about 243 m above sea level (Ghana Statistical Service, 2021). The study area is mostly based on rainforests and shares boundaries with Ahafo Ano South West District, Ahafo Ano South East District, Asutifi South District, Tano South District and Tano North District. Majority of the inhabitants of the study area are farmers and it is one of the most significant cocoa growing districts in Ghana. It occupies an area of 593 - kilometer square. It has an estimated income earning population of about 92,742 (Ghana Statistical Service, 2021).

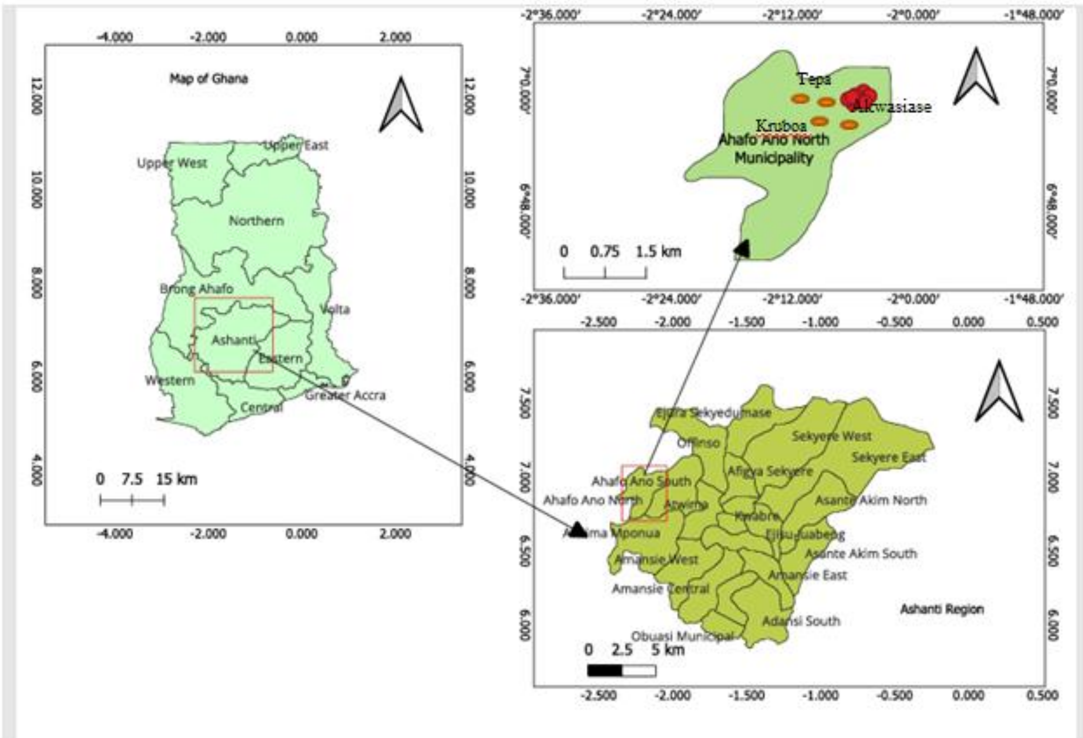

Figure 3.1 Map of the study area (Ghana Statistical Service, 2021).

3.2 Sample Collection

Five medicinal plants (*Azadirachta indica, Calotropis procera, Cassia alata, Theobroma cacao, and Vernonia amygdalina*) predominantly used by the inhabitants with their immediate soils were randomly picked from Akwasiase, Kruboa and Tepa in the Ahafo Ano - North Municipality. For each medicinal plant, the roots and leaves were selected for analysis. Each sample was picked in triplicates. The collected samples were washed and dried in the shade (32°C - 40°C) for three days. Powdered samples were produced from plant parts which were divided into three, one part was crushed using mortar and pestle, another part was grinded using stone, another part was pulverized using blender. All powdered samples were sieved using a 2 mm mesh, package in zipped bags and prepared for analysis. Each powdered sample in the zipped bag were firmly sealed and properly labeled.

Soil samples were collected at (0 to 15) cm depth from sites where the medicinal plants were rooted using plastic trowel. Hazardous metals usually pollute top layer of soils at a depth of (0 to 40) cm (Sarpong & Dartey, 2017). A background soil sample was picked from the Tinte Bepo forest reserve where no human activities take place. The soil was collected at (0 to 15) cm depth using plastic trowel, firmly sealed and properly labeled in a zipped bag.

3.3 Sample preparation

Heavy metal assessment was made using known weights of the samples in crucibles made of porcelain. The contents of crucibles were dried at 110 °C and moistened with magnesium nitrate (50% w/v). Ashing was done using ceramic fiber muffle furnace at a temperature of 450 ºC and left overnight to ensure complete oxidation of organic components of the sample. After which, samples were cooled in a desiccator and were digested with 2:5 mixture of concentrated acids (70% $HClO_4$ and 70% HNO_3) in a microwave digester to allow thorough dissolution of ash in acid. Heating continued until the brown fume of nitric acid ceased and the sample turned clear. The digestion was stopped and distilled water added to obtain a total volume of 50 ml. The digested solution of each plant sample and soil sample was made up to 100 ml using deionized water. Each sample solution was filtered using Whatman 41 filter paper in order to obtain a particle-free solution and stored in clean glass vials. Hazardous metal concentrations were determined using atomic absorption spectrometer. The instrument setting and operational conditions were in accordance with the manufacturers specifications (Sarpong & Dartey, 2017 ; Sadhu et al., 2015).

3.4 Instrumentation

The stored filtrates of samples were used for analysis of hazardous metals using atomic absorption spectrophotometer. All sample analysis was done in triplicates. Blank solutions were prepared in a similar modus operandi and the absorbance values were deducted as background. Concentration of each hazardous metal was established from absorbance value of each triplicate and represented in mg/kg on a dry weight basis of the plant and soil samples (Sadhu et al., 2015). The instrument was set up in accordance to the manufacturer's specifications with the wavelength corresponding to that of the element under study.

3.5 Quality control and assurance

Analysis of the present research was taken through quality assurance procedures to ensure accurate and reliable results. Blank solutions were prepared to examine possibility of contamination to medicinal plant samples by reagents and/or glassware used in the analysis (Sarpong et al., 2022). This incorporated meticulous cleaning and soaking of plastic and glassware in 5% HNO_3 solution for 24 hours before use (Gyamfi et al., 2023). Absolute care was taking in the handling of samples to prevent contamination. A recovery study was conducted to validate the accuracy and precision of the analytical procedure employing the spike recovery procedure.

3.6 Heavy metal analysis

The study employed Atomic Absorption Spectrophotometer to analyze the concentrations of Pb, Cd, Mn, Cu, and Zn in medicinal plant samples. The hazardous metal concentrations in each plant and soil sample were determined from the calibration curves, and the instrument recorded the results in milligram per kilogram (Sarpong et al., 2022).

3.7 Blank Samples Preparation

To prepare the blank samples, 20 ml each of 2M aqueous magnesium nitrate solution was put into five different 20 g capacity porcelain crucibles. The crucibles and contents were put into the muffled oven and heated at 450 ºC until solutions were dried. Reconstitution of solutions was with 20 ml of HNO_3 and $HClO_4$ mixture (5:2). The reconstituted solutions were put into five different 200 ml digestion tubes and boiled gently at 95 ºC until dense white fumes appeared. After digestion, 20 ml of de-ionized water was added to each digestion tube, shaken vigorously for 5 minutes, and filtered through Whatman No.41 filter paper. Filtrate volumes were made to 50 ml with de-ionized water and then analyzed exactly as done for medicinal plant samples (Sarpong et al., 2022)

3.8 Statistical analysis

The data were analyzed using the JASP statistical package version 0.18.3.0. Descriptive statistical parameters such as mean and standard deviation (SD) were used to describe the heavy metal concentration in the medicinal plant samples and soil samples. T - test was used to determine if there is a significant difference between the mean concentrations of heavy metal in medicinal plant samples at a significance level of $p < 0.05$.

3.9 Test of Significance of Hazardous Metal Contamination

Test of significance was conducted for the various metals within the research area with the following hypothesis.

Null: The mean hazardous metals within different plant parts are same for the grinding procedures.

Alternative: The mean hazardous metals within different plant parts are *not* same for the grinding procedures.

The test was conducted at 95% confidence interval with 5% significance level for the testing.

3.10 Modelling of Human Health Risk Assessment

3.10.1 Exposure model

Hazardous metals in plants and soils enter the human body chiefly via ingestion. In this study, health risk assessment of metals in plants and soil sample were analyzed using the oral ingestion scenario to recipient (adult and children for plants only) based on the USEPA (2002) risk assessment methodology.

The exposure doses in plants usually boiled was computed using equation 1 and that in soils was estimated using equation 2 for oral respectively.

$$D_{ing\text{-}w} = \frac{Cw \times IR \times EF \times ED}{BW \times AT} \ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

$$D_{ing\text{-}s} = \frac{Cs \times IR \times EF \times ED \times CF}{BW \times AT} \ldots\ldots\ldots\ldots\ldots\ldots 2$$

The variable Ding-w and Ding-s are the exposure dose through ingestion of water and soil (mg/kg/day) respectively, Cw and Cs are the concentration of metal in plant and soil respectively and IR: ingestion rate, EF: exposure frequency, ED: exposed duration, BW: average body weight, AT: average time and CF: unit conversion factor. The values of these parameters are listed in table 3.1. The reference dose was obtained from Ghana Environmental Protection Agency (2014) as indicated in Table 3.1

Table 3.1 Input Parameters for Human Health Risk Assessment (Sarpong et al., 2022)

Exposure Factors	Units	Adults	Children	Reference Dose	
Ingestion rate	ml/d	30	15	Pb	0.01
Exposure Frequency	days/yr	30	30	Cu	2
Exposure Duration	Yrs	1	1	Zn	0.3
Average time	days/yr	25550		Cd	0.005
Body weight (Adult)	kg	80		Mn	0.14
Conversion Factor C- oral		0.001			
Body weight (Children)	kg		15		

3.10.2 Human Health Risk Estimation

The health risk of Pb, Cd, Zn, Mn and Cu in the medicinal plants were assessed using the expected daily intake (EDI) of the metals, Hazard Index (HI), and Hazard Quotient (HQ) as employed elsewhere (Kortei et al., 2020). Hazard Quotient is the ratio of exposure to hazardous substances to the chronic reference dose of the toxicant (mg kg^{-1} d^{-1}) (Nkansah et al., 2016).The EDI of Pb, Cd, Zn, Mn and Cu were calculated to assess expected average quantities of each metal that consumers are likely to be exposed to daily in equation 1. The hazard quotient (HQ) and hazard index (HI) were used to characterize the health risk on non-carcinogens on humans due to exposure to toxicants (Sarpong et al., 2022) in equations 2 and 3 respectively**.** These indices were computed using the relations below;

For non - carcinogens:

EDI = $\frac{Cmetal \times IR}{BW}$ ……………….1

HQ = $\frac{EDI}{RefD}$ ……………….2

HI = $\sum_{i=1}^{n} HQi$ ……………….3

HI=Σ (HQMn + HQPb + HQCd + HQZn + HQCu) …………..4

The variables IR represents Ingestion rate, BW represents Body Weight, EDI and R_{ef} D represent the estimated daily intake (mg/kg/d) and reference dose (mg/kg/d) respectively. The reference dose for non-carcinogens is listed in Table 3.2

Table 3.2 Oral reference dose (R_{ef} D) for hazardous metals in water and soil (mg/kg/d)

Metal	R_{ef} D in soil	R_{ef} D in water
Pb	0.01	0.004
Cu	2	0.04
Cd	0.005	0.001
Zn	0.3	0.3
Mn	0.14	0.14

Sarpong et al., (2022).

The classification based on Sarpong et al. (2022) were used to assess the level of risk on the health of humans. If Hazard Quotient is less than 1 (HQ < 1), as interpreted in comparable studies indicates that likely occurrence of non-cancerous diseases amongst patrons of the medicinal plants from long-term usage of the drugs investigated is non-existence, if Hazard Quotient is greater than 1 (HQ > 1), then there exists health risk to humans by the particular hazardous metal.

Moreover, the Hazard Index (HI) estimates the cumulative health risk of all the hazardous metals present in the plant sample, when HI > 1 then there exists a probable health risk associated with the plant medicine as a result of a combination of all the hazardous metals present. The parameters used for calculation of hazard quotient HQ in medicinal plants is listed in Table 3.3

Table 3.3 Input Parameters for Human Health Risk Assessment

(Kortei et al., 2020 ; Sarpong et al., 2022)

		Medicinal plants	
Exposure Factors	**Units**	**Adult**	**Children**
Ingestion rate	g/d	30	15
Exposure Frequency	days/yr	30	30
Exposure Duration	Yrs	1	1
Averaging Time	days/yr	25550	
Body Weight (Adult)	kg	80	
Body Weight (Children)		0.001	
Conversion Factor C oral	hr/day	0.6	
Exposure time (Adult)	kg	15	15
Exposure time (Children)	hr/day	0.54	

Table 3.4 Input Parameters for Human Health Risk Assessment

(Kortei et al., 2020 ; Sarpong et al., 2022)

	Soil Samples	
Exposure Factors	**Units**	**Adult**
Ingestion rate	mg/d	15
Exposure Frequency	days/yr	52
Exposure Duration	Yrs	35
Averaging Time	days/yr	25550
Body Weight (Adult)	kg	80

Conversion Factor C Oral		0.001
Exposure Time (Adult)	hr/day	0.6

The geo-accumulation index, (Igeo) was employed to evaluate the extent of pollution of hazardous metals in soil samples. The geo-accumulation index relation used:

$Igeo = \ln (Cn_{Sample} / 1.5 \times Bn)$

Where: Cn = measured concentration of metal in the soil (mg/l) Bn= background value of heavy metal in mg/l; and 1.5 = background matrix correction factor.

The Bioconcentration Factor (BCF), Translocation Factor (TF), and Bioaccumulation Coefficient (BAC) were evaluated by the following relations as applied by Sarpong & Dartey (2017), Takarina & Pin (2017) and Rezapour et al.(2023) using the equations 1,2 and 3 respectively

- Bioconcentration Factor (BCF) = $\frac{\text{[Metals] roots}}{\text{[Metals] soil}}$ ……………1
- The Translocation Factor (TF) = $\frac{\text{[Metals] shoot}}{\text{[Metals] roots}}$ ……………2
- Bioaccumulation Coefficient (BAC) = $\frac{\text{[Metals] shoot}}{\text{[Metals] soil}}$ ………..3

The standard conditions employed for the operation of the atomic absorption spectrometer is listed in Table 3.5.

Table 3.5 Standard conditions for atomic absorption measurement (Lokhande et al., 2010)

Elements	Wavelength /nm	Band width / nm	Sensitivity check / ppm	Detection limit / ppm	Lamp current / mA
Pb	283.31	0.4	0.18	0.03	5.0
Cd	228.80	0.4	0.012	0.0028	5.0
Cu	324.75	0.4	0.03	0.004	5.0
Zn	213.86	0.4	0.01	0.003	5.0
Mn	279.48	0.4	0.02	0.002	5.0

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Physicochemical Characteristics of Soil Samples

Table 4.1 presents the physicochemical variables for the sampled plant soils. This is to appreciate the role of certain parameters that could possibly enhance the movement of hazardous metals in the soil.

Table 4.1: Physicochemical parameters of soils around the medicinal plants

Soil	pH	EC/µS/cm	TDS/mg/l	SOM / %
Soil Theobroma cacao	6.37	130.60	18.60	5.47
Vernonia amygdalina	6.57	121.60	28.10	3.96
Calotropis procera	7.04	120.40	27.84	6.66
Cassia alata	7.52	128.30	15.20	4.99
Azadirachta indica	5.32	125.90	27.87	5.12

Table 4.1.a Descriptive Statistics for each parameter

Parameter	Mean	Std Deviation	Minimum	Maximum	p-value
pH	6.63	0.83	5.32	7.52	0.012
EC	125.3	4.51	120.4	130.6	0.71
TDS	23.52	6.35	15.20	28.10	0.65
SOM	5.20	1.07	3.96	6.66	0.082

4.1.1 Soil pH

The pH values of the soil samples ranged from 5.32 to 7.52, which fall within the acceptable range of 6.0 - 8.5 set by the Ghana Environmental Protection Agency - EPA, and 6.5 - 8.5 recommended by world health organization WHO, except for *Azadirachta indica,* which is slightly acidic. The pH value for normal soil is in the range 5.5 - 7.5, pH of soils below this range can cause low availability of some essential minerals needed by the soil (Abdulhamid et al., 2015). The result showed that soil pH values of all the soil samples analyzed from the five medicinal plants indicate slightly acidic to neutral soil conditions, suitable for most medicinal plants.

Theobroma cacao and *Azadirachta indica* soils have slightly acidic pH, while *Vernonia amygdalina*, *Calotropis procera*, and *Cassia alata* soils have neutral pH. This also is an indication that the soil samples were within the range for normal soil pH. These values are in the same range of 5.0 - 7.5 as reported by Anapuwa (2014) for soils from Nigeria. The pH values in this study 5.32-7.52 are similar to those reported by Dartey & Sarpong (2016). The pH values obtained from the current test are also lower than values 7.2 - 8.3 for soil samples in India (Abdulhamid et al., 2015). The pH values of the soil samples vary significantly between plants, with *Theobroma cacao* and *Azadirachta indica* having the most distinct pH values.

4.1.2 Soil Organic Matter Content

The results for soil organic matter content values of all the soil samples analyzed from the five medicinal plants varied from 3.96 to 6.66%, as indicated in Table 4.1. The amount of soil organic matter content of each plant soil was; *Cassia alata* (4.99), *Azadirachta indica* (5.12), *Theobroma cacao* (5.47), *Vernonia amygdalina* (3.96) and *Calotropis procera* (6,66) all in percentages. The organic matter content values, ranging from 3.96 to 6.66%, indicate moderate to high levels of organic matter in the soils. *Calotropis procera* and *Theobroma cacao* soils have higher organic matter content values, suggesting better soil fertility and structure. Organic matter plays a crucial role in soil fertility, structure, and water-holding capacity, and high levels can benefit plant growth.

Calotropis procera had the highest soil organic matter content with *Vernonia amygdalina* having the least. This observation substantiated with Ojo et al. (2015) who reported that polluted soils had significant higher soil organic matter and organic carbon as compared to uncontaminated or controlled sites. The higher organic matter content in the soil under *Calotropis procera* may be as a result of the plant known to be a fast-growing plant that can contribute to the accumulation of organic matter in the soil (Quazi et al., 2013). The plant's roots can help break down organic matter and make it available for other plants to absorb. Additionally, the plant's leaves and stems can add organic matter to the soil when they decompose. The organic matter content values (3.96 - 6.66%) are lower than those reported by Anapuwa (2014) for soils from the forest zones of Ghana (7 - 12%). No significant differences were found in soil organic matter values between plants.

4.1.3 Soil Electrical conductivity (EC)

The results for soil electrical conductivity values of all the soil samples analyzed from the five medicinal plants varied from 120.4 to 130.6 µS/cm as indicated in Table 4.1. The electrical conductivity values, however, are below the recommended range of 400 - 600 µS/CM, indicating low conductivity (Abdulhamid et al., 2015). The EC values (120.4 - 130.6 µS/cm) indicate moderate soil conductivity, suggesting adequate nutrient availability. *Theobroma cacao* and *Cassia alata* soils have slightly higher EC values, indicating higher nutrient levels.

The values of electrical conductivity in each plant soil were; *Cassia alata* (128.3), *Azadirachta indica* (125.9), *Theobroma cacao* (130.6), *Vernonia amygdalina* (121.6) and *calotropis procera* (120.4). *Theobroma cacao* had the highest soil conductivity with

Calotropis procera having the least. The EC values (120.4 - 130.6 µS) are lower than those reported by Dartey & Sarpong (2016) for soils from the Kumasi metropolis (145-230 µS/cm). These EC values may be beneficial for plant growth, but excessive nutrient levels can be harmful. No significant differences were found in electrical conductivity values between plants.

4.1.4 Soil Total Dissolved Solids (TDS)

The results for soil total dissolved solids values of all the soil samples analyzed from the five medicinal plants ranged from 15.20 – 28.10 mg/l as indicated in Table 4.1. The values of total dissolved solids in each plant soil were; *Cassia alata* (15.20), *Azadirachta indica* (27.87), *Theobroma cacao* (18.60), *Vernonia amygdalina* (28.10) and *Calotropis procera* (27.84) all in milligram per liter. The TDS values vary among the plant species, but all fall within the acceptable range of 200 - 500 mg/l recommended by WHO and Ghana EPA (Obeid et al., 2013). *Theobroma cacao* and *Cassia alata* have relatively low TDS levels, while *Vernonia amygdalina*, *Calotropis procera*, and *Azadirachta indica* have slightly higher levels. The TDS values, ranging from 15.20 to 28.10 ppm, indicate low to moderate levels of dissolved solids in the soils (Abdulhamid et al., 2015). The TDS values (15.20 - 28.10 mg/l) are lower than those reported by Osei et al (2019) for soils from the Accra plains (30 - 50 mg/l). *Vernonia amygdalina* and *Calotropis procera* soils having higher TDS values, suggests higher levels of dissolved nutrients. TDS values obtained from this research suggest that these medicinal plants prefer well-draining, fertile soils with adequate nutrient availability. This may be beneficial for plant growth, but excessive levels can be harmful. No significant differences were found in total dissolved solids values between plants.

4.2 Metals Concentration Analysis

The results of determination of hazardous metals in soils recorded in mg/kg are presented in Table 4.2 and concentrations of hazardous metals in medicinal plants are represented in Tables 4.3 to 4.5. Data generated were presented as mean values of results obtained from the triplicates of each analysis.

The table below represents the concentrations of heavy metals in soils of the selected medicinal plant samples.

Table 4.2 Heavy metals concentration in soils around the medicinal plants.

	Conc in mg/kg				
SOIL	**Pb**	**Zn**	**Cu**	**Cd**	**Mn**
Theobroma cacao	2.851	1.954	1.765	0.074	8.890
Vernonia amygdalina	0.693	2.712	0.518	0.037	6.516
Calotropis procera	0.754	1.490	0.337	0.018	9.629
Cassia alata	1.722	6.423	0.792	0.055	1.323
Azadirachta indica	0.523	1.114	1.267	0.039	9.125

The table below represents the concentrations of heavy metals in a background soil.

Table 4.2a Heavy metals concentration in background soil (Forstner et al., 1993).

Metal	Concentration in mg/kg
Cd	0.012
Zn	0.010
Cu	0.030
Pb	0.179
Mn	0.020

The descriptive Statistics for metals in soils of medicinal plants is listed in Table 4.3 below.

Table 4.3 Descriptive Statistics for metals in soils around medicinal plants in mg/kg

Metal	Mean	Std Deviation	Minimum	Maximum	p-value
Pb	1.308	1.034	0.523	2.851	0.014
Zn	2.738	2.033	1.114	6.423	0.031
Cu	0.936	0.541	0.337	1.765	0.082
Cd	0.044	0.022	0.018	0.074	0.023
Mn	8.898	3.511	1.323	9.629	0.123

The table presents descriptive statistics for the concentrations of five metals (Cd, Cu, Mn, Pb, and Zn) in the average soils across all the soils sampled under the medicinal plants. The test reveals; Significant differences in Pb, Zn, and Cd concentrations between different plant soils ($p < 0.05$). *Theobroma cacao* and *Vernonia amygdalina* have significantly different Pb concentrations ($p < 0.05$). *Cassia alata* and *Azadirachta indica* have significantly different Zn concentrations ($p < 0.05$). *Theobroma cacao* and *Calotropis procera* have significantly different Cd concentrations ($p < 0.05$).

The concentrations of the heavy metals in the samples showed that all the studied metals were present in all soil samples. Mean concentrations: Cd: 0.04 (low), Cu: 0.94 (moderate), Mn: 8.90 (high), Pb: 1.31 (moderate) and Zn: 2.74 (moderate). Standard Deviation (SD): Cd: 0.02 (low variability), Cu: 0.58 (moderate variability), Mn: 1.44 (moderate variability), Pb: 0.98 (high variability) and Zn: 2.14 (high variability). Range: Cd: 0.06 (narrow), Cu: 1.43 (moderate), Mn: 3.81 (moderate), Pb: 2.33 (moderate) and Zn: 5.31 (wide) (Abdulhamid et al., 2015). The study reveals varying levels of metal concentrations in soils of medicinal plants, with Mn having the highest mean concentration and Cd the lowest. The standard deviation values indicate moderate to high variability in metal concentrations, suggesting potential hotspots of contamination. The range of values highlights the need for further investigation to understand the sources and fate of these metals in the soil. Even though levels of Cd were detected, the concentrations recorded for Cd were very insignificant.

This result agrees with the study on heavy metals in soils from Ishaigu in Nigeria conducted by Ogbonna et al. (2013) where Cd was not detected in most farm sites. It is also similar to results of heavy metals analysis of soils of Bijapur Taluka in India where out of ten farms analyzed, Cd and Pb were not detected in two farms (Abdulhamid et al., 2015 ; Ojo et al., 2015). Copper levels in this study (0.94) were higher than levels obtained in the same geological study in the Volta Region (2.40 ± 1.5 mg/kg). Manganese levels in this study (8.90) were lower than levels obtained in the same geological study in the Volta Region (4.72 ± 0.8 mg/kg).

Lead levels in this study (1.31) were lower than levels obtained in the same geological study in the Volta Region (0.53 ± 0.02 mg/kg). Zinc levels in this study (2.74) were lower than levels obtained in the same geological study in the Volta Region (7.74±1.5mg/kg) (Kortei et al., 2020).

Table 4.4 Concentration Ranges of Metals (mg/kg) in Soils and medicinal Plants by WHO (Forstner et al., 1993).

Hazardous Metals	Permissible levels in Plants	Permissible levels in Soils
Cadmium	0.02	0.80
Copper	10.0	36
Manganese	2.20	-
Lead	2.00	85
Zinc	0.60	50

The WHO maximum permissible limits of metals in soil samples from medicinal plants are as illustrated in Table 4.4 above (Abdulhamid et al., 2015). These heavy metals detected in the soil samples were below the permissible limits. In general, the concentration of the metals in the soil samples varied according to the following trend Mn > Zn > Pb > Cu > Cd, indicating that the entire soil sample had higher level of manganese (Mn) and lower level of cadmium (Cd).

Table 4.5 shows the classification index for geo-accumulation to ascertain the contamination intensity in soils.

Table 4.5 Geo- accumulation index classification (Forstner et al., 1993)

Geo-accumulation index (Igeo)	Igeo	Contamination intensity
> 5	6	Very strong
$> 4 - 5$	5	Strong to very strong
$> 3 - 4$	4	Strong
$> 2 - 3$	3	Moderate to strong
$> 1 - 2$	2	Moderate
$> 0 - 1$	1	Uncontaminated to moderate
< 0	0	Practically uncontaminated

Table 4.6 presents the geo-accumulation index (Igeo) values for metals in soils of medicinal plants

Table 4.6 Geo accumulation index of metals in soils of individual medicinal plants.

Metal	***Theobroma cacao***	***Vernonia amygdalina***	***Calotropis procera***	***Cassia alata***	***Azadirachta indica***
	Igeo	**Igeo**	**Igeo**	**Igeo**	**Igeo**
Pb	2.36	0.95	1.03	1.86	0.67
Zn	4.87	5.19	4.59	6.06	4.31
Cu	3.67	2.44	2.01	2.87	3.34
Cd	1.41	0.72	0	1.12	0.77
Mn	5.69	5.38	5.77	3.78	5.72

The results suggest that the plants have different geo accumulation patterns for different metals.

Table 4.7 Geo accumulation index of mean metal levels in soils of medicinal plants.

Metal	Igeo
Pb	1.58
Cd	0.80
Cu	3.04
Zn	5.21
Mn	5.69

The Igeo values indicate the level of metal accumulation in the soils, providing insights into the contamination intensity. The study reveals varying levels of metal contamination in soils of medicinal plants, with Zn and Mn showing the highest levels of accumulation. Pb: Igeo value of 1.58 indicates moderate contamination. Cd: Igeo value of 0.80 suggests uncontaminated to moderate contamination. Cu: Igeo value of 3.04 indicates strong contamination. Zn: Igeo value of 5.21 indicates strong to very strong contamination. Mn: Igeo value of 5.69 indicates strong to very strong contamination. The strong to very strong contamination intensity for Cu, Zn, and Mn suggests potential environmental and health risks. The moderate contamination level for Pb and uncontaminated to moderate level for Cd indicate lower risks.

4.3 Heavy Metals in Medicinal Plants

Heavy metals may exist either as a deposit on the surface of medicinal plants, or may be taken up by the crop roots and incorporated into the edible part of plant tissues. Heavy metals are the major contaminates of food and medicine supply and may be considered the most important problems to our environment. Heavy metals deposited on the surface can often be eliminated simply by washing prior to consumption, whereas bio-accumulated metals are difficult to remove (Wuana & Okieimen, 2011).

Concentration of metals in medicinal plants taken through different grinding procedures are listed in Table 4.8, Table 4.9 and Table 4.10

Table 4.8 Concentration of metals in plant part taken through SG procedure

	Roots (mg/l)					Shoots (mg/l)				
Plants	**Pb**	**Zn**	**Cu**	**Cd**	**Mn**	**Pb**	**Zn**	**Cu**	**Cd**	**Mn**
Theobroma Cacao	0.731	0.244	0.870	0.013	0.622	0.424	0.633	0.621	0.014	0.401
Vernonia amygdalina	0.443	0.197	0.482	0.037	0.196	0.134	0.491	0.145	0.015	0.245
Calotropis procera	0.712	0.658	0.683	0.028	0.645	0.406	0.842	0.737	0.019	0.334
Cassia alata	0.051	0.401	0.213	0.073	0.980	0.154	0.763	0.353	0.015	0.139
Azadiractha indica	0.653	0.342	0.526	0.035	0.167	0.002	0.830	0.477	0.014	0.239

Table 4.9 Concentration of metals in plant part taken through MPG procedure

	Roots (mg/l)					Shoots (mg/l)				
Plants	**Pb**	**Zn**	**Cu**	**Cd**	**Mn**	**Pb**	**Zn**	**Cu**	**Cd**	**Mn**
Theobroma Cacao	0.697	0.296	0.786	0.018	0.123	0.391	0.608	0.535	0.015	0.309
Vernonia amygdalina	0.314	0.175	0.521	0.006	0.514	0.090	0.425	0.113	0.011	0.199
Calotropis procera	0.568	0.493	0.734	0.032	0.522	0.433	0.680	0.741	0.015	0.261
Cassia alata	0.044	0.432	0.309	0.030	0.085	0.124	0.679	0.417	0.017	0.116
Azadiractha indica	0.295	0.324	0.346	0.006	0.118	0.001	0.713	0.496	0.019	0.224

Table 4.10 Concentration of metals in plant part taken through BG procedure

	Roots (mg/l)					Shoots (mg/l)				
Plant	**Pb**	**Zn**	**Cu**	**Cd**	**Mn**	**Pb**	**Zn**	**Cu**	**Cd**	**Mn**
Theobroma Cacao	0.703	0.215	0.736	0.009	0.587	0.437	0.567	0.551	0.008	0.530
Vernonia amygdalina	0.397	0.079	0.545	0.035	0.187	0.113	0.373	0.084	0.016	0.215
Calotropis procera	0.621	0.527	0.718	0.023	0.539	0.541	0.870	0.691	0.018	0.264
Cassia alata	0.053	0.394	0.322	0.032	0.087	0.099	0.591	0.435	0.013	0.146
Azadiractha Indica	0.373	0.270	0.440	0.017	0.132	0.015	0.756	0.398	0.025	0.226

Table 4.8.1 Descriptive Statistics for metals in plant part taken through SG procedure

Metal	Mean conc (mg/l) in Roots	Roots p-value	Mean conc (mg/l) in Shoots	Shoots p-value
Pb	0.518	0.033	0.244	0.012
Zn	0.388	0.082	0.632	0.051
Cu	0.555	0.123	0.466	0.041
Cd	0.037	0.019	0.015	0.132
Mn	0.542	0.023	0.291	0.085

There is a significant difference found in Pb, Cd, and Mn concentrations in the roots, and Pb and Cu concentrations in the shoots between plants. *Theobroma cacao* and *Cassia alata* have significantly different Pb concentrations in the roots ($p < 0.05$). *Azadirachta indica* and *Cassia alata* have significantly different Cd concentrations in the roots ($p < 0.05$). *Theobroma cacao* and *Vernonia amygdalina* have significantly different Mn concentrations in the roots ($p < 0.05$). *Calotropis procera* and *Azadirachta indica* have significantly different Pb concentrations in the shoots ($p < 0.05$).

Table 4.9. 1 Descriptive Statistics for metals in plant part taken through MPG procedure

Metal	Mean conc (mg/l) in Roots	Roots p-value	Mean conc (mg/l) in Shoots	Shoots p-value
Pb	0.384	0.019	0.208	0.023
Zn	0.344	0.082	0.590	0.132
Cu	0.539	0.051	0.461	0.041
Cd	0.018	0.033	0.014	0.082
Mn	0.272	0.123	0.212	0.051

A significant difference was found in Pb and Cd concentrations in the roots, and Pb and Cu concentrations in the shoots between plants. *Theobroma cacao* and *Cassia alata* have significantly different Pb concentrations in the roots ($p < 0.05$). *Calotropis procera* and *Cassia* *alata* have significantly different Cd concentrations in the roots ($p < 0.05$). *Theobroma cacao* and *Azadirachta indica* have significantly different Pb concentrations in the shoots ($p < 0.05$).

Table 4.10.1 Descriptive Statistics for metals in plant part taken through BG procedure

Metal	Mean conc (mg/l) in Roots	Roots p-value	Mean conc (mg/l) in Shoots	Shoots p-value
Pb	0.355	0.007	0.239	0.012
Zn	0.258	0.051	0.503	0.041
Cu	0.548	0.123	0.392	0.082
Cd	0.020	0.023	0.012	0.132
Mn	0.309	0.033	0.251	0.051

Significant differences were found in Pb, Cd, and Mn concentrations in the roots, and Pb and Zn concentrations in the shoots between plants. *Theobroma cacao* and *Azadirachta indica* have significantly different Pb concentrations in the roots ($p < 0.05$). *Calotropis procera* and *Cassia alata* have significantly different Cd concentrations in the roots ($p < 0.05$). *Theobroma cacao* and *Vernonía amygdalina* have significantly different Mn concentrations in the roots ($p < 0.05$).

4.3.1 Leaves

Descriptive statistics for the concentrations of five metals (Cd, Cu, Mn, Pb, and Zn) in the leaves of medicinal plants revealed the following data. The means and standard deviations of hazardous metals in leaves taken through stone grinding (SG) were; Cd (0.02 ± 0.00288), Cu (0.47 ± 0.023), Mn (0.27 ± 0.10), Pb (0.22 ± 0.18) and Zn (0.71 ± 0.15). Theobroma Cacao (Cocoa) leaves have the highest concentration of Pb (0.424) and Cu (0.621), indicating potential toxicity. *Calotropis procera* leaves have the highest concentration of Zn (0.842) and Mn (0.334), suggesting a high accumulation of these essential micronutrients. *Vernonia amygdalina* leaves have relatively low concentrations of all metals, indicating a potential for safe use. *Azadiractha indica* leaves have a very low concentration of Pb (0.002), suggesting a low risk of Pb toxicity. The concentration of metals in leaves of medicinal plants taken through the Blender grinding (BG) procedure was also analyzed. *Vernonia amygdalina* had the highest uptake for Mn, with a concentration of 0.215 mg/kg in its leaves. *Azadiractha indica* had the highest absorption for Cd, with a concentration of 0.025 mg/kg in its leaves, highlighting the need for further research on its potential for phytoremediation.

The concentration of metals in leaves of medicinal plants taken through the Mortar and Pestle Grinding (MPG) procedure was analyzed as; *Theobroma cacao* having a higher uptake for Pb, with a concentration of 0.391 mg/kg in its leaves. *Calotropis procera* had a higher metal uptake for Zn and Cu, with concentrations of 0.680 mg/kg and 0.741mg/kg in its leaves, respectively.

Vernonia amygdalina shows relatively low concentrations of all metals, suggesting a safer profile for potential uses. Calotropis procera, on the other hand, accumulates high levels of zinc (Zn) and manganese (Mn), which are essential micronutrients for plants and humans. However, excessive exposure to these metals can still be harmful.

4.3.2 Roots

Descriptive statistics for the concentrations of five metals (Cd, Cu, Mn, Pb, and Zn) in the roots of medicinal plants showed the following data. The means and standard deviations of hazardous metals in roots of medicinal plants taken through stone grinding SG were; Cd (0.03 ± 0.02), Cu (0.51 ± 0.23), Mn (0.40 ± 0.27), Pb (0.37 ± 0.27) and Zn (0.34 ± 0.24) as shown in Appendix4. *Theobroma Cacao* roots have high concentrations of Pb (0.73) and Cu (0.87), indicating potential metal toxicity. *Calotropis procera* roots have high concentrations of Zn (0.66), *Cassia alata* had the highest manganese level Mn (0.98), suggesting a high accumulation of essential micronutrients. *Cassia alata* roots have relatively high concentration for Cd (0.07), which is higher than the other plants. *Azadiractha indica* roots have moderate concentrations of all metals, with a relatively low concentration of Mn (0.17).

The concentration of metals in roots of medicinal plants taken through the Blender grinding (BG) procedure was also analyzed. *Theobroma cacao* had the highest concentration of Pb (0.703 mg/kg) and Cu (0.736 mg/kg) in its roots, suggesting its potential for phytoremediation of these metals. *Calotropis procera* had the highest concentration of Zn (0.527 mg/kg) in its roots, indicating its potential for phytoremediation of Zn. *Cassia alata* had the lowest concentration of Pb (0.053 mg/kg) in its roots compared to other plant species. *Theobroma cacao* had a higher concentration of Cu (0.736 mg/kg) in its roots compared to other plant species.

The concentration of metals in roots of medicinal plants taken through the Mortar and Pestle Grinding (MPG) procedure was analyzed as; *Theobroma cacao* had a higher concentration of Pb (0.697 mg/kg) in its roots compared to other plant species. *Calotropis procera* had a higher concentration of Zn (0.493 mg/kg) and Cu (0.734 mg/kg) in its roots, suggesting its potential for phytoremediation of these metals. *Theobroma cacao* had a higher concentration of Pb and Cu in its roots compared to its shoots. *Calotropis procera* had a higher concentration of Zn and Cu in its roots compared to its shoots. The study reveals varying levels of metal concentrations in the roots of medicinal plants, with Cu having the highest mean concentration and Cd the lowest.

4.3.3 Comparison of Metal Concentration in Medicinal Plant Sample Parts

The study demonstrated variation in the levels of hazardous metals in selected medicinal plant parts. Levels of metals determined in medicinal plant parts from sites in Tepa municipality were as presented in Table 4.8, Table 4.9 and Table 4.10

- *Theobroma Cacao* roots have higher Pb and Cu concentrations than leaves.
- *Vernonia amygdalina* roots have lower metal concentrations than leaves.
- *Calotropis procera* roots have higher Zn and Mn concentrations than leaves.
- *Cassia alata* roots have lower metal concentrations than leaves, except for Cd.
- *Azadirachta indica* roots have higher Pb and lower Zn concentrations than leaves.

4.3.4 Metals in Plants taken through different Grinding Procedures

The analysis of metal concentrations in medicinal plants reveals significant differences depending on the grinding procedure used. The results show that stone grinding (SG) and blender grinding (BG) result in higher metal concentrations compared to mortar and pestle grinding (MPG). This suggests that the mechanical action of stone and blender grinding may be releasing more metals to the plant material, potentially contaminating the final product.

The data reveals a consistent pattern of decreasing metal concentrations across the three grinding methods. For instance, the concentration of manganese (Mn) decreases from 0.622 mg/kg in SG to 0.123 mg/kg in MPG in roots of *theobroma cacao*, while the concentration of lead (Pb) decreases from 0.731 mg/kg in SG to 0.697 mg/kg in MPG in roots cocoa. This trend suggests that the mortar and pestle grinding method may be less likely to introduce metal contaminants into the medicinal plants. The mortar and pestle grinding method is a traditional technique that involves manually grinding the plant material using a pestle and mortar, which is typically made of wood.

The findings have important implications for the processing and handling of medicinal plants. The use of stone and blender grinding methods may pose a risk of metal contamination, which could have adverse effects on human health. In contrast, the mortar and pestle grinding method appears to be a safer option, as it results in lower metal concentrations.

4.4 Bioconcentration Factor, Bioaccumulation Coefficient and Translocation Factor

Bioconcentration Factor (BCF), bioaccumulation coefficient (BAC) and translocation factor (TF) are parameters employed as indicators for plant metal transfers from soil to roots, soil to shoots and roots to shoots. Bioconcentration Factor (BCF), bioaccumulation coefficient (BAC) and translocation factor (TF) of magnitudes > 1 had been employed to assess the ability of medicinal plant for Phyto-extraction and Phyto-stabilization (Sarpong & Dartey, 2017).

The accumulation and concentration of heavy metals in medicinal plants substantially depends on the extent of uptake of these elements by plants from the soil. The transfer coefficients of all metals vary extensively. For example, lead (Pb), copper (Cu) and Manganese (Mn) have lower transfer coefficients, meaning they remain stably bound to soil structures, and hence show minimum transfer to plants. On the other hand, metals like zinc (Zn) and cadmium (Cd) have higher transfer coefficients, that is, they are readily taken up from the soils by plants (Sadhu et al., 2015).

Phytoextraction is the process whereby toxic metals are removed from soils by plants and thereby preserving soil structure and fertility (Wuana & Okieimen, 2011 ; Rezapour et al., 2023). High values of translocation factor TF (that is, high shoot to root) is a demonstration of the plant species susceptibility to transfer metals and possess needed characteristics to be utilized in phyto-extraction.

4.4.1 Translocation Factor (TF)

The translocation factor (TF) values of medicinal plants taken through different procedures (SG, BG, and MPG) were analyzed to understand the plants' ability to translocate metals from roots to shoots. Translocation is the absorption of soil minerals, water and nutrients by roots and transported from the roots to the shoot system of the plant (Wuana & Okieimen, 2011 ; Mondal & Chakraborty, 2016). In Table 4.11, the translocation factor of *Theobroma cacao* for Pb is 0.580 in stone grinding, while in Table 4.12 it is 0.622 for blender grinding and in Table 4.13, it is 0.516 for mortar and pestle grinding procedure. *Theobroma cacao* showed higher TF values for Zn and Cu in the BG procedure compared to the SG and MPG procedures as shown in Table 4.11, Table 4.12 and Table 4.13 respectively. *Vernonia amygdalina* had higher TF values for Mn in the SG and MPG procedures compared to the BG procedure. *Cassia alata* showed high TF values for Pb and Mn in all procedures, indicating its potential for phytoremediation of these metals. *Azadirachta indica* had high TF values for Cd in the MPG procedure, suggesting its potential for phytoremediation of Cd. Plant species like *Cassia alata and Azadirachta indica* could be used for phytoremediation of metal-contaminated soils.

Azadirachta indica, *Cassia alata* and *Vernonia* amygdalina with TF >1 [*Azadirachta indica* (1.431), *Cassia alata* (1.418) and *Vernonia amygdalina* (1.249)] had potential for phyto-extraction for Mn polluted soil. *Theobroma cacao* (1.000), TF > 1 for the study area for Cd had potency to act as phyto-extraction agent. *Cassia alata* (2.851), with TF > 1 for Pb had ability to function as phyto-extraction agent for the said metal from lead contaminated soil. *Calotropis procera* (1.079) and *Cassia alata* (1.657), with TF > 1 for Cu had the capacity to perform the function of phyto-extraction agent for Cu contaminated soils. Translocation factor for all the plant samples for zinc was found to be greater than one and hence each of them had the efficacy for phyto-extraction of Zn from the soil as indicated in Table 4.11. There are significant differences in Pb, Cu, and Cd translocation factor values between plants and procedures ($p < 0.05$).

Phyto-stabilization is the phenomenon of terminating soil pollutants by suppressing the relocation of contaminants via wind and water erosion, leaching and soil dispersion as a result of absorption and accumulation by roots system of plants (Takarina & Pin, 2017). Phyto-stabilization can modify the solubility and mobility of contaminants and thus prevents their dispersion through wind or water. Phyto-stabilization is dependent on the roots gravitation to prevent contaminants movement and bioavailability in the soils (Wuana & Okieimen, 2011).

Table 4.11, table 4.12 and table 4.13 illustrates the Translocation factor of medicinal plants taken through varied grinding procedures

Table 4.11 Translocation factor of medicinal plants taken through SG procedure

Medicinal plant	Translocation factor				
	Pb	**Zn**	**Cu**	**Cd**	**Mn**
Theobroma Cacao	0.580	2.694	0.714	1.000	0.644
Vernonia amygdalina	0.302	2.492	0.301	0.405	1.249
Calotropis procera	0.729	1.279	1.079	0.678	0.518
Cassia alata	2.851	1.902	1.657	0.205	1.418
Azadiractha indica	0.003	2.427	0.907	0.400	1.431

Table 4.12 Translocation factor of medicinal plants taken through BG procedure

Medicinal plant	Translocation factor				
	Pb	**Zn**	**Cu**	**Cd**	**Mn**
Theobroma Cacao	0.622	2.637	0.749	0.888	0.902
Vernonia amygdalina	0.285	2.722	0.154	0.457	1.154

Calotropis procera	0.871	1.651	0.962	0.783	0.489
Cassia alata	1.867	1.500	1.351	0.406	1.678
Azadiractha indica	0.040	2.800	0.905	1.471	1.707

Table 4.13 Translocation factor of medicinal plants taken through MPG procedure

Medicinal plant	**Translocation factor**				
	Pb	**Zn**	**Cu**	**Cd**	**Mn**
Theobroma Cacao	0.561	2.054	0.681	0.833	0.590
Vernonia amygdalina	0.287	2.429	0.215	0.275	1.139
Calotropis procera	0.762	1.365	1.009	0.531	0.498
Cassia alata	2.818	1.571	1.349	0.566	1.365
Azadiractha indica	0.003	2.201	1.434	3.167	1.898

4.4.2 Bioaccumulation Coefficients (BAC)

The bioaccumulation coefficient (BAC) values of medicinal plants taken through different procedures (SG, BG, and MPG) were analyzed to understand the plants' ability to accumulate metals in their tissues.

Bioaccumulation is defined as the accumulation of a substance over time inside a single organism. It also implies the buildup of absorbed chemicals here in metals in an organism (plants) over time (Wuana & Okieimen, 2011) The bioaccumulation coefficients BAC of the analyzed medicinal plants exhibited differences in magnitude as shown in Table 4.14, Table 4.15 and Table 4.16 for stone grinding, blender grinding and mortar and pestle grinding respectively.

Theobroma cacao showed higher BAC values for Zn and Mn in the SG procedure compared to the BG and MPG procedures. *Vernonia amygdalina* had higher BAC values for Cd in the BG procedure compared to the SG and MPG procedures. *Calotropis procera* showed high

BAC values for Cu and Cd in all procedures, indicating its potential for phytoremediation of these metals. *Azadirachta indica* had high BAC values for Zn in the BG and MPG procedures, suggesting its potential for phytoremediation of Zn.

In Table 4.14, the maximum and minimum BAC for Pb was recorded in *Calotropis procera* (0.843) and *Azadirachta indica* (0.004) respectively. Highest BAC for Cd was *Calotropis procera* (1.056) while the lowest was in *Theobroma cacao* (0.176). Highest and lowest BAC for Cu were recorded in *Calotropis procera* (2.19) and *Vernonia amygdalina* (0.279) respectively. Similar recordings for maximal and minimal BAC values of zinc metal occurred in *Azadirachta indica* (0.745) and *Cassia alata* (0.119). In parallel, the greatest and least BAC for Mn was documented for *Theobroma cacao* (0.452) and *Cassia alata* (0.135). A significant difference in Pb and Cu bioaccumulation coefficient values between plants and procedures ($p < 0.05$) was seen. The analysis revealed that the *Calotropis procera* might be considered for application as excluder for cadmium (Cd) and copper (Cu) (Sarpong & Dartey, 2017). Table 4.14, Table 4.15 and Table 4.16 illustrates the bio-accumulation coefficient of medicinal plants taken through varied grinding procedures

Table 4.14 Bio-accumulation coefficient of medicinal plants taken through SG procedure

	Bio-accumulation coefficient				
Medicinal plant	**Pb**	**Zn**	**Cu**	**Cd**	**Mn**
Theobroma Cacao	0.148	0.324	0.351	0.176	0.452
Vernonia amygdalina	0.193	0.191	0.279	0.405	0.377
Calotropis procera	0.843	0.565	2.187	1.056	0.347
Cassia alata	0.089	0.119	0.446	0.273	0.135
Azadiractha indica	0.004	0.745	0.376	0.359	0.263

Table 4.15 Bio-accumulation coefficient of medicinal plants taken through BG procedure

Medicinal plant	Bio-accumulation coefficient				
	Pb	Zn	Cu	Cd	Mn
Theobroma Cacao	0.153	0.290	0.312	0.108	0.596
Vernonia amygdalina	0.163	0.138	0.162	0.432	0.331
Calotropis procera	0.718	0.584	2.050	1.000	0.274
Cassia alata	0.057	0.092	0.549	0.236	0.142
Azadiractha indica	0.040	0.679	0.314	0.641	0.248

Table 4.16 Bio-accumulation coefficient of medicinal plants taken through MPG procedure

Medicinal plant	Bio-accumulation coefficient				
	Pb	Zn	Cu	Cd	Mn
Theobroma Cacao	0.131	0.311	0.303	0.203	0.349
Vernonia amygdalina	0.130	0.157	0.218	0.300	0.305
Calotropis procera	0.574	0.456	2.199	0.833	0.271
Cassia alata	0.072	0.106	0.527	0.309	0.113
Azadiractha indica	0.002	0.640	0.391	0.487	0.246

4.4.3 Bioconcentration Factor BCF

The bioconcentration factor (BCF) values of medicinal plants taken through different procedures (SG, BG, and MPG) were analyzed to understand the plants' ability to accumulate metals in their tissues.

Bioconcentration deals with the levels or concentration of a chemical in a particular organism becoming higher than its concentration in the environment around the organism (Takarina & Pin, 2017). Medicinal plants with high bioconcentration factor (BCF) and low translocation factor (TF) qualify to be used for phyto-stabilization of toxic chemicals in soils (Lazaro et al., 2006). High BCF values imply that plant retains metals in their roots and restricts metal movement from roots to the shoots system after absorption by the roots (Cui et al., 2007). *Calotropis procera* with BCF (1.16); TF (0.72), and *Azadirachta indica* with BCF (1.25); TF (0.003) for Pb may be considered for phyto-stabilization of Pb contaminated soil. Almost all the medicinal plant samples had BCF for Cd > 1 except *Theobroma cacao* (0.17) and *Azadirachta indica* (0.89) as indicated in table 4.17. Translocation factor TF for the rest of the medicinal plants; *Vernonia amygdalina* (0.41), *Calotropis procera* (0.67) and *Cassia alata* (0.21) were found to be less than one and hence had phyto-stabilization properties for cadmium.

In Table 4.17, Table 4.18 and Table 4.19, *Theobroma cacao* showed higher BCF values for Pb and Cu in the SG procedure compared to the BG and MPG procedures. *Vernonia amygdalina* had higher BCF values for Mn in the SG procedure compared to the BG and MPG procedures. *Calotropis procera* showed high BCF values for Cu and Cd in all procedures, indicating its potential for phytoremediation of these metals. *Azadirachta indica* had high BCF values for Pb in the SG and MPG procedures, suggesting its potential for phytoremediation of Pb. Significant differences in Pb and Cu bioconcentration factor values between plants and procedures ($p < 0.05$).

Table 4.17, Table 4.18 and Table 4.19 illustrates the bioconentration factors of medicinal plants taken through varied grinding procedures

Table 4.17 Bioconcentration factor of medicinal plants taken through SG procedure

	Bioconcentration factor				
Medicinal plant	**Pb**	**Zn**	**Cu**	**Cd**	**Mn**
Theobroma Cacao	0.256	0.125	0.493	0.176	0.699

Vernonia amygdalina	0.639	0.073	0.931	1.000	3.814
Calotropis procera	1.156	0.381	2.027	1.556	0.671
Cassia alata	0.031	0.062	0.269	1.327	0.095
Azadiractha indica	1.249	0.307	0.415	0.897	0.184

Table 4.18 Bioconcentration factor of medicinal plants taken through BG procedure

	Bioconcentration factor				
Medicinal plant	**Pb**	**Zn**	**Cu**	**Cd**	**Mn**
Theobroma Cacao	0.247	0.110	0.417	0.122	0.650
Vernonia amygdalina	0.573	0.029	1.052	0.946	0.282
Calotropis procera	0.824	0.354	2.131	1.278	0.560
Cassia alata	0.030	0.061	0.406	0.581	0.841
Azadiractha indica	0.713	0.242	0.347	0.438	0.153

Table 4.19 Bioconcentration factor of medicinal plants taken through MPG procedure

	Bioconcentration factor				
Medicinal plant	**Pb**	**Zn**	**Cu**	**Cd**	**Mn**
Theobroma Cacao	0.224	0.151	0.445	0.243	0.581
Vernonia amygdalina	0.453	0.065	1.006	1.081	0.260
Calotropis procera	0.753	0.334	2.178	1.778	0.543
Cassia alata	0.026	0.067	0.390	0.545	0.822
Azadiractha indica	0.564	0.291	0.273	0.154	0.133

4.8 Descriptive Statistics for concentration of metals in Medicinal Plants

Figure 4.1 present descriptive statistics for the concentrations of metals (Cd, Cu, Mn, Pb, and Zn) in the leaves of medicinal plants taken through SG. The statistics provide an overview of the central tendency, dispersion, and range of values for each metal.

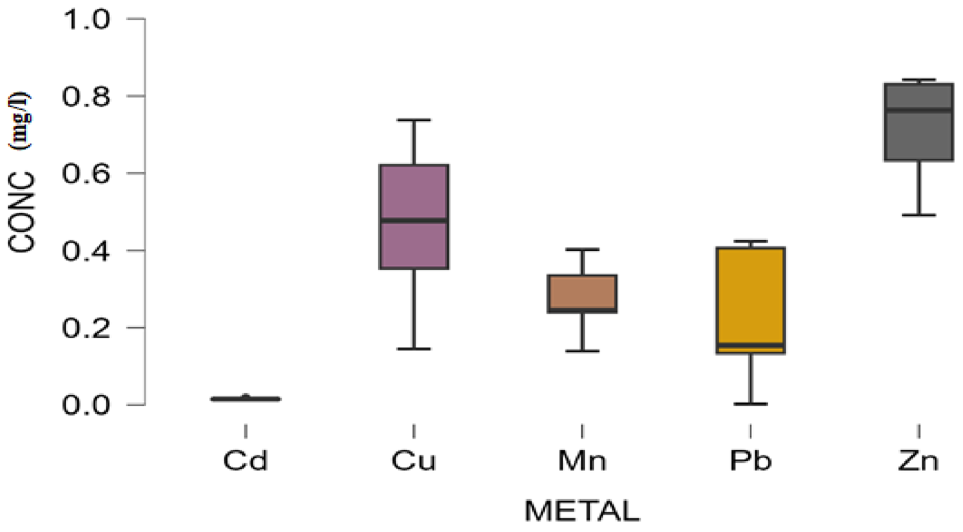

Figure 4.1 Graph of concentration of metals in leaves of medicinal plants taken through SG

Figure 4.2 present descriptive statistics for the concentrations of five metals (Cd, Cu, Mn, Pb, and Zn) in the roots of medicinal plants taken through SG

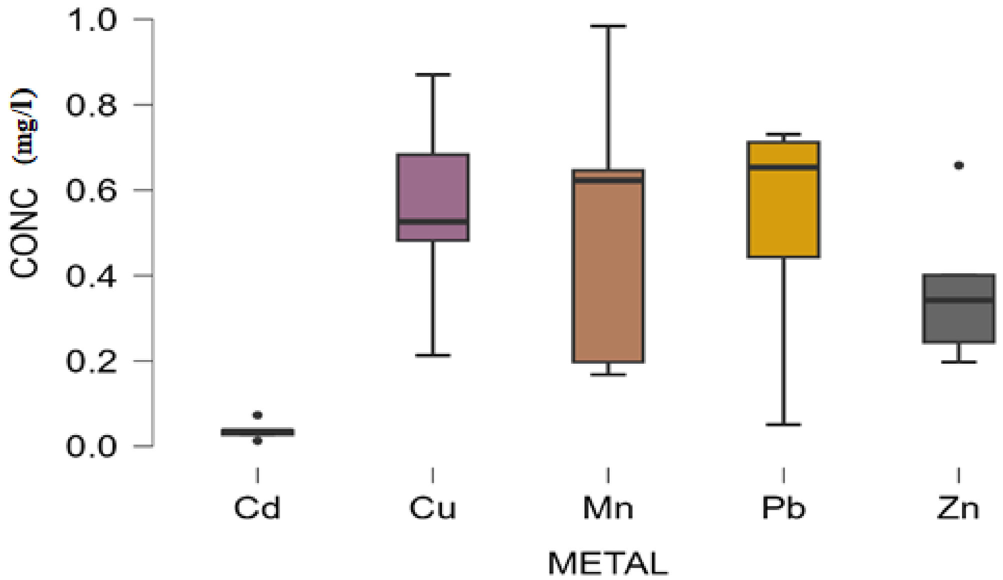

Figure 4.2 Graph of concentration of metals in roots of medicinal plants taken through SG

Figure 4.3 presents descriptive statistics for the concentrations of metals in the leaves of medicinal plants taken through BG.

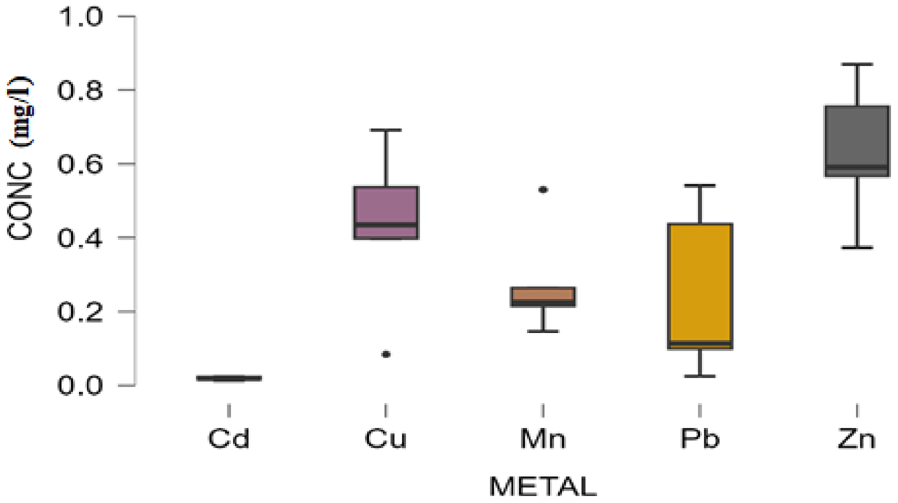

Figure 4.3 Graph of concentration of metals in leaves of medicinal plant via BG

Figure 4.4 below present descriptive statistics for the concentrations of metals in the roots of medicinal plants taken through MPG.

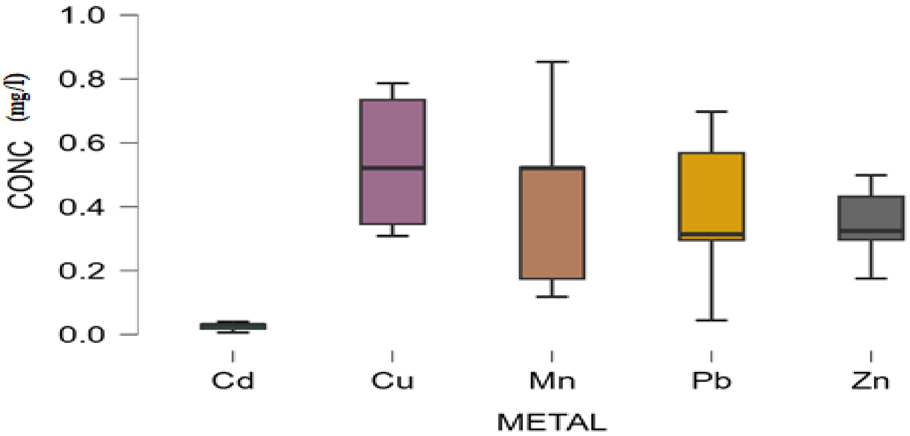

Figure 4.4. Graph of concentration of metals in roots medicinal plants taken through MPG

Figure 4.5 presents descriptive statistics for the concentrations of metals in the leaves of medicinal plants taken through MPG.

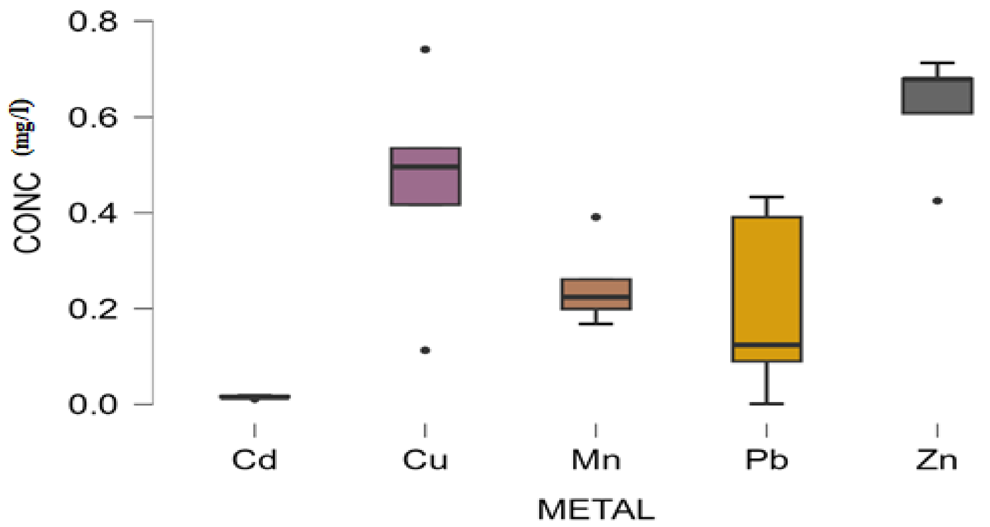

Figure 4.5 Graph of concentration of metals in leaves medicinal plants taken through MPG

Figure 4.6 presents descriptive statistics for the concentrations of metals in the roots of medicinal plants taken through BG.

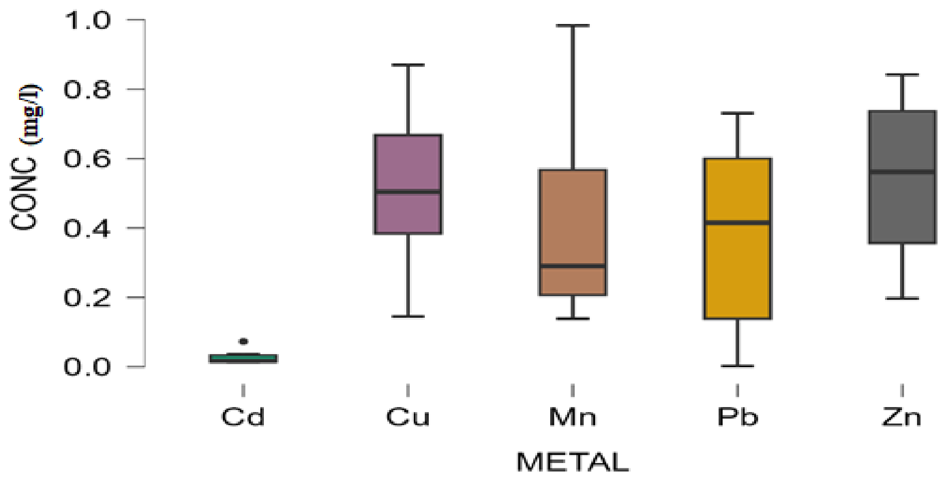

Figure 4.6 Graph of concentration of metals in the roots of medicinal plants taken through BG.

Table 4.20 Analysis of Variance for the Roots of Plant Samples

			95% Confidence Interval	
Metals	**Mean**	**SD**	**F**	**P**
Pb	0.494	0.321	4.32	0.012
Zn	0.332	0.191	3.19	0.043
Cu	0.632	0.221	2.51	0.093
Cd	0.024	0.018	1.83	0.183
Mn	0.419	0.261	2.21	0.133

Table 4.21 Analysis of Variance for the Leaves of Plant Samples

			95% Confidence Interval	
Metals	**Mean**	**SD**	**F**	**P**
Pb	0.321	0.193	3.51	0.031
Zn	0.589	0.221	2.83	0.061
Cu	0.449	0.221	2.19	0.143
Cd	0.014	0.006	1.49	0.253
Mn	0.293	0.141	1.92	0.173

4.9.1 Copper (Cu)

The Cu levels in all the medicinal plant samples were within the WHO recommended limit of 2.0 mg/kg as observed in Table 4.8, Table 4.9 and Table 4.10. The highest and least Cu levels in the roots was observed to be present (0.87mg/kg) in *Theobroma cacao* and (0.21mg/kg) in *Cassia alata* respectively in Table 4.8. Meanwhile the maximum and minimum levels in the leaves were recorded in *Calotropis procera* (0.74 mg/kg) and *Vernonia amygdalina* (0.15 mg/kg) respectively. The average concentration of copper content was determined to be 0.54 ± 0.23 mg/kg. According to literature, Cu levels in medicinal plants consumed in Turkey and Lebanon were found to be 3.5mg/kg and 0.88mg/kg respectively (Ojezele et al., 2021). These concentrations of copper in Lebanon are higher than those observed in the present study. Again, the concentrations of copper in *Calotropis procera* and *Cassia alata* from Turkey are higher than those observed in the present study.

The high Cu levels in medicinal plants might have stem from low pH and high Cu contents of soils in areas where raw materials were sourced. This examination is consistent with observation made in cognate studies (Sarpong et al., 2022). The possible low soil pH might have contributed in highly mobile and unrestrictedly accessible Cu-ions for absorption by roots of the plant as seen in similar studies (Ojezele et al., 2021). Unrestricted anthropogenic copper release into the environments of medicinal plants from human activities plays a vital role in high Cu levels in medicinal plants. Frequent intake of these plants could activate liver damage, abdominal pain cramps, nausea, diarrhea and vomiting, as reported in a comparable study conducted (Sarpong et al., 2022). Statistically no significant difference ($P > 0.05$) was observed in mean Cu levels among the selected medicinal plants. Cu metal in agricultural soils absorbed by plants becomes especially important in seed production, disease resistance, and regulation of water. Copper plays important roles in bone formation, mineralization of the skeleton, preventing damage to cell structure and as an antioxidant assisting in free radical scavenging. Symptoms of copper deficiency include inability to concentrate, fatigue and a poor mood. Low amounts of copper are associated with low dopamine levels (Ojimelukwe & Amaechi, 2019). Genetic diseases are sometimes caused by the body's inability to properly utilize copper, if it is present in excess.

4.9.2 Lead (Pb)

The Pb concentrations in the various parts of the medicinal plants examined are in range of 0.051 mg/kg (*Cassia alata*) to 0.731 mg/kg (*Theobroma cacao*) in the roots and in the order of *Azadirachta indica* (0.002 mg/kg) to *Theobroma cacao* (0.437 mg/kg) in the leaves. However, the mean concentration of lead in all plants is 0.408 ± 0.27mg/kg. According to the World Health Organization (WHO) the permissible levels of this hazardous metal in medicinal plants is 10mg/kg, and findings from this research revealed that all lead (Pb) concentrations were within the acceptable range. The mobility of the non-essential metal from roots to leaves is comparably higher (Takarina & Pin, 2017). In leaves, Pb is toxic, especially for the plant functions of photosynthesis and the synthesis of chlorophyll and antioxidant enzymes. Sometimes, the roots can prevent the transport of non-essential metals, so metals accumulates mostly in the roots (Takarina & Pin, 2017). In this test *Theobroma cacao* was determined to have the highest concentration of lead. The high levels of lead in cocoa are probably linked to some of the farming practices carried out by the farmers. Application of fertilizers containing phosphates, spraying of some weedicides which contain phosphate to control the growth of weeds among others. There is statistically a significant difference ($P < 0.05$) was observed in mean Pb levels among the selected medicinal plants.

4.9.3 Manganese (Mn)

In this study, concentration of Mn in the plant raw root materials ranged from 0.17 mg/kg in *Azadirachta indica* to 0.98 mg/kg in *Cassia alata* as illustrated in Table 4.8. Manganese content of plant leaves ranged from 0.116 to 0.530 mg/kg. The mean manganese content was calculated to be 0.356 ± 0.27 mg/kg. In this test higher concentrations were determined in the soil and hence the plants. Increased Mn content was observed in plant samples like *Cassia alata* (0.98 mg/kg) and *Calotropis procera* (0.65). Hence, use of medicinal plants like *Cassia alata* and *Calotropis procera* as a supplement for Mn must looked into (Lokhande et al., 2010). Mn is one different trace element which is essential to many metabolic processes. It functions as a substance whose presence is essential for many enzymes. Its toxicity to organisms is less compared to other metals, but continuous exposure to higher doses as part of dust and fumes can cause neurological disorders (Eng, 2020). In as much as the values were seen to be relatively high in the plant samples, all the concentrations were comparatively lower values than the WHO and EPA guidelines/standards. The accumulation of manganese Mn in living organisms including plants has the potential of reaching toxic levels in human and thereby victims' show signs of dullness, weak muscles, headaches and insomnia (Dartey, 2015 ; Sadhu et al., 2015). Statistically no significant difference ($P > 0.05$) was observed in mean Mn levels among the selected medicinal plants. This implies that all the mean values are not different for a given plant.

4.9.4 Zinc (Zn)

The concentration of Zn in roots of medicinal plants varied from 0.079mg/kg in *Vernonia amygdalina* to 0.658mg/kg in *Calotropis procera*. Again, the concentration of Zn in the leaves of medicinal plants varied from 0.373 mg/kg in *Vernonia amygdalina* to 0.870 mg/kg in *Calotropis procera* as indicated in Table 4.8, Table 4.9 and Table 4.10. The high concentration of zinc in roots of *Cassia alata* and *Calotropis procera* suggests its possible use in sex tonic, treatment of worms, skin disease, and eye trouble. Conversely, very high concentrations of Zn compounds are corrosive and irritating to the skin, eye, mucous membrane and digestive tract causing nausea, vomiting and special types of dermatitis known as "zinc pox"(Dartey, 2015). For all that, the mean concentration of zinc in all plants is 0.461 mg/kg. However, the mean zinc concentrations detected in the roots and leaves of all plants were below the specified guidelines or standards and may not manifest the associative toxicity symptoms stated on the humans who resort to these plants as a source of medicine in the short run (Singare & Talpade, 2013). Statistically no significant difference ($P > 0.05$) was observed in mean Zn levels among the selected medicinal plants. This implies that all the mean values are not different for a given plant.

4.9.5 Cadmium (Cd)

The concentration of cadmium in the plant samples were found to be within the range of 0.006 – 0.073 mg/kg with the highest level in root and leave samples occurring in *Cassia alata* (0.073 mg/kg) and *Azadirachta indica* (0.025 mg/kg) respectively. On the other hand, the lowest level of cadmium in samples was determined in *Vernonia amygdalina* (0.006 mg/kg) and *Theobroma cacao* (0.008 mg/kg) roots and leaves respectively. The mean cadmium concentration was ascertained to be 0.019 ± 0.02 mg/kg. There is statistically no significant difference detected in mean cadmium metal concentration levels among the selected medicinal plants. Cadmium has no known biological function in humans; it usually accumulates in kidneys and liver, and also it has long half-life of 4–19 years (Al Zabadi et al., 2018). Albeit, cadmium Cd is one of the most critical toxic elements for humans and one major issue of concern for soil scientist and environmental researchers. This problem is more critical in suburban areas and cultivated lands subjected to different kinds of human-related pollution. Extensive research has reported somewhat similar conditions in all parts of the world concerning cadmium. For instance, Rezapour et al., (2019) in Iran, have reported far-reaching Cd pollution of soils rooted in the application of wastewater, mineral activities, industrial activities, and effluent disposal. As well, cadmium transmission from polluted land to different soils has been reported in various parts of the world. There is no statistically significant difference in the mean of the metals under study found in the different parts of a given plant.

4.10 Hazard Quotient and Hazard Index

In interpreting the HQ, a value < 1 indicates an exposure lower than the reference dose. A daily exposure at this level is unlikely to cause any adverse effects during a person's lifetime, whereas a HQ ≥ 1 is an indication of possible adverse health effects (Solomon et al., 2022)

Table 4.22 Hazard Quotient for selected metals in Soils of medicinal plants.

Metals	HQ for Adults	HQ for Children
Cd	1.1×10^{-4}	5.7×10^{-4}
Cu	6.3×10^{-6}	3.3×10^{-5}
Mn	8.5×10^{-4}	4.5×10^{-3}
Pb	1.8×10^{-3}	9.3×10^{-3}
Zn	1.2×10^{-4}	6.5×10^{-4}

Heavy metals in soil can have devastating health effects, particularly for vulnerable populations like children. This study computes the HI for adults and children exposed to heavy metals in soil, using the following formula:

HI = Σ (HQ metal), where HQ metal is the Hazard Quotient for each metal (Pb, Cu, Zn, Cd, and Mn).

Table 4.23 Hazard Indices of metals to adults and children

Population	HI
Adults	2.89×10^{-3}
Children	1.5×10^{-2}

Children have a higher HI (1.5×10^{-2}) compared to adults (2.89×10^{-3}), suggesting a greater health risk. The HI for children is approximately 5 times higher than for adults, emphasizing the need for targeted interventions to mitigate exposure. The dominant contributors to the HI for children are cadmium (Cd) and zinc (Zn), while lead (Pb) and Zn are the primary contributors for adults. This suggests that children are more susceptible to the harmful effects of Cd and Zn, which can lead to developmental delays, neurotoxicity, and other health problems.

From the individual hazard quotients calculated for the individual metals in the soils all the HQ values obtained was less than 1, which is an indication of no cancer risk. Although the hazard index (HI) is less than 1, their cumulative effect is of concern. The HI of children is slightly greater than that of adults which suggest that heavy metal contamination possess more risk to children than adults. The results of this study are however lower than what was reported by

Nkansah et al., 2016 on heavy metal content and potential health risk of soils from the Kumasi metropolis in Ghana with HI = 0.064.

Table 4.24 Hazard Quotient for selected metals in medicinal plants amongst adults and children based on different grinding methods.

Metals	HQ for SG		HQ for BG		HQ for MPG	
	Adults	**Children**	**Adults**	**Children**	**Adults**	**Children**
Cd	7.9×10^{-3}	2.1×10^{-2}	5.3×10^{-3}	1.4×10^{-2}	5.3×10^{-3}	1.4×10^{-2}
Cu	3.4×10^{-3}	8.9×10^{-3}	3.2×10^{-3}	8.6×10^{-3}	3.1×10^{-3}	8.3×10^{-3}
Mn	7.7×10^{-3}	2.1×10^{-2}	6.9×10^{-3}	1.9×10^{-2}	6.4×10^{-3}	1.7×10^{-2}
Pb	2.4×10^{-2}	6.5×10^{-2}	2.3×10^{-2}	5.9×10^{-2}	1.9×10^{-2}	5.3×10^{-2}
Zn	4.8×10^{-4}	1.3×10^{-3}	4.1×10^{-4}	1.1×10^{-3}	4.2×10^{-4}	1.1×10^{-3}

Table 4.25 Hazard Indices for selected metals in medicinal plants amongst adults and children based on different grinding methods.

Method	HI adults	HI children
SG	4.3×10^{-2}	1.2×10^{-2}
BG	3.9×10^{-2}	1.0×10^{-1}
MPG	3.4×10^{-2}	9.3×10^{-2}

Grinding methods can affect metal bioavailability, and age is a crucial factor in metal toxicity. This study assesses the hazard indices of medicinal plants processed through three grinding methods: Stone Grinding (SG), Blender Grinding (BG), and Mortar and Pestle Grinding (MPG). Stone grinding as a process of plant crushing poses a higher hazard index for adults (4.3×10^{-2}) compared to children (1.2×10^{-2}). Blender Grinding shows a higher hazard index for children (1.0×10^{-1}) than adults (3.9×10^{-2}). Mortar and Pestle Grinding exhibits high hazard index for children than adults. Prolonged consumption of medicinal plants with high metal content can lead to adverse health effects, including neurotoxicity, nephrotoxicity, and carcinogenicity. The age-dependent differences in hazard indices suggest that children may be more vulnerable to metal toxicity due to their developing organs and systems.

Considering the HI and HQ data obtained (HI < 1 and HQ <1) in Table 4.24 and Table 4.25 , all the medicinal plants happens to be safe for management and treatment of the various health conditions and ailments indicated for them, as presented in analogous investigations (Sarpong et al., 2022). This is an indication that the individual metals and the combined effects of the metals studied currently, is not likely to induce any of the health conditions usually associated with them.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This research was conducted in the Ahafo - Ano North Municipality, Ghana to analyze the presence and levels of potentially hazard elements in soils and medicinal plants from different areas. The study revealed that soils from the Ahafo - Ano North Municipal were slightly acidic to alkaline and their pH values were within the pH range for natural soils. It was revealed that the metal concentrations of Pb, Cd, Zn, Cu and Mn in the soils were lower than the WHO/EPA and maximum permissible limits MPL for the respective metals. In general, the concentration of the metals in the soil samples varied according to the following trend Mn > Zn > Pb > Cu > Cd.

The pollution indices such as geo-accumulation index was employed to estimate the extent of the potentially hazard metal contamination. Again, the study sought to determine the risk to human health. Geo-accumulation index for soils from the Municipal exhibited some similarities in Mn and Zn whose contamination was strong to very strong, uncontaminated to moderately contaminated with Cd, moderate contaminated with Pb and moderate to strong contaminated with Cu. All the soils have high risk. The entire risk assessment for the ecological risk was observed to be of very high risk for the sites in the Ahafo - Ano North Municipal.
The contamination factor for the Ahafo Ano - North Municipal revealed that most of the soils from the sampled sites were of low contamination with Pb, Cd, and Cu. Soils were very highly contaminated with Mn and Zn.

The levels of hazardous metals in the medicinal plants were lower than the WHO/GEPA maximum permissible limits for the respective metals. Most of the medicinal plants had Cd levels lower than the WHO/GEPA for Cd. Pb, Cd and Zn levels in medicinal plants grinded with stones were slightly higher than those obtained from parts taken through blender grinding and mortar and pestle grinding. Conversely, the levels of hazardous metals in the medicinal plants macerated from mortar and pestle had the least values.

Almost all the medicinal plants selected would act as phytoextractors for Zn. All the medicinal plants could act as phytoextractors by way of bioconcentration factor BCF: soil to root and bioaccumulation coefficient BAC: soil to shoots. The translocation and accumulation patterns of hazardous metals vary for each element, the kind of plant and the growth season. Elements such as copper and zinc appeared to be distributed more evenly throughout the plants. Soils would not have deleterious effects on the health of the population. The medicinal plants were found to be non-toxic to consumers. The findings however showed that children are more susceptible to metal toxicity. The coefficient of variation values obtained at a 95% confidence level across the five soils revealed significant differences in the concentration of potentially hazard metals like Cu and Mn in soils from Ahafo Ano North ($p > 0.005$) as shown in Table 4.3. Again, the same observation was made for medicinal plants taken through different grinding procedures.

5.2 Recommendation

Findings obtained from this work must be communicated to the Ahafo Ano North Municipal Assembly and to the traditional herbal medicine practitioners through workshops, seminars etc. Traditional herbal medicine practitioners must be educated on the negative effects of hazardous metals and measures to reduce metal contamination in herbal products.

The inhabitants of the area who mostly are farmers must be educated on good farming practices in terms of farm input applications. That is applying correct amount of fertilizers, weedicides and other chemicals in the quest of protecting crops or controlling weed growth. For the reason that areas where medicinal plants were gathered from are within and close to farmlands, farmers must be educated on harmful effects of agrochemicals.

Mostly, hazardous substances are absorbed and translocated from the environment and that human activities such mining must be controlled to guarantee a reduction in concentrations of toxic metals released into the locality. Again, the levels of hazardous metals in the atmosphere must be investigated since leaves of medicinal plants absorb metal fragments through their pores. Solvents used for preparing tradition herbal medicines must analyzed for hazardous metal content before use since solvents with high hazardous metals results in unhealthy products.

Inhabitants of the area must be educated to desist from rampant and indiscriminate burning of solid refuse as well as avoid open disposal of waste as it can increase the concentrations of hazardous metals. Healthcare practitioners and traditional medicine practitioners should consider the grinding method and age group when prescribing medicinal plants. Further studies should investigate the effects of grinding methods on metal bioavailability and toxicity in medicinal plants. Regulatory agencies should establish guidelines for safe processing and handling of medicinal plants.

REFERENCES

Abdulhamid, Z., Agbaji, E., & Gimba, C. (2015). *Physicochemical Parameters and Heavy Metals Content of Soil Samples from Farms in Minna*. *September 2016*. https://doi.org/10.18052/www.scipress.com/ILCPA.58.154

Abubacker, M. N., Ramanathan, R., & Kumar, T. S. (2008). *In vitro antifungal activity of Cassia alata Linn . flower extract*. *7*(1), 6–9. https://doi.org/10.7454/mss.v21i2.7308

Adella, B. S. (2017). *An Ethnographic Review of Grinding, Pounding, Pulverizing, and Smoothing with Stones. PCAS Quarterly 32(4),* https://www.researchgate.net/publication/265480727

Agyarko, K., Dartey, E., & Berlinger, B. (2011). *Assessment of metal levels of some refuse* *dump soils in Ghana*. 101–105. https://doi.org/10.7454/

Al Zabadi, H., Sayeh, G., & Jodeh, S. (2018). Environmental exposure assessment of cadmium, lead, copper and zinc in different Palestinian canned foods. *Agriculture and Food Security*, *7*(1), 1–7. https://doi.org/10.1186/s40066-018-0205-1

Alonso-castro, A. J., Maldonado-miranda, J. J., Zarate-martinez, A., Figueroa-zun, L. A., Jacobo-salcedo, R., Ferna, C., Andre, N., Rios-reyes, N. A., Leo, M. A. De, Carranza-alvarez, C., Reyes-munguia, A., & Me, R. (2012). *Medicinal plants used in the Huasteca Potosina , Me*. *143*, 292–298.

Amankwah, D. (2013). *Levels of some heavy metals and proximate analyses of cocoa beans from Eastern and Central regions of Ghana*. *March*.

Ameyaw, Y., Barku, V. Y. A., Ayivor, J., & Forson, A. (2012). *Phytochemical screening of some indigenous medicinal plant species used in the management of diabetes mellitus in Ghana*. *6*(30), 4573–4581. https://doi.org/10.5897/JMPR12.564

Anapuwa, O. S. (2014). *Heavy Metal Contamination and Characteristics of Soils from Automobile Workshops in Abraka , Delta State , Nigeria Keywords : 2*(4), 48–58.

Baloch, S. (2021). *Essential and Non-Essential Elements in Medicinal Plants : A Review*. 26098–26100. https://doi.org/10.26717/BJSTR.2021.33.005446

Bilal, H., Ali, I., Uddin, S., Khan, I., Said, A., Rahman, M. U., Khan, A. M., Shah, A. B., & Ali, A. (2020). *Biological evaluation of antimicrobial activity of Calotropis procera against a range of bacteria*. *9*(1), 31–35.

Brhane, G. & Dargo, H. (2014). *International Journal of Emerging Trends in Science and Technology A Review on Hydrogen as an Alternative Fuel*. *1*(9), 1394–1403.

Brima, E. I. (2022). *Pilot Study of Trace Elements in the Infusion of Medicinal Plants Used for Diabetes Treatment*. *2022*. https://doi.org/10.4491/esr.2016.004

Burke, I. C., & Schimel, D. (2014). *Texture, Climate, and Cultivation Effects on Soil Organic Matter Content in U.S. Grassland Soils*. *May*. https://doi.org/10.2136/sssaj1989.03615995005300030029x

Canadian Council of Ministers of the Environment,CCME (2016) Guidance Manual For Environmental Site Characterization in Support of Environmental and Human Health Risk Assessment Volume 4 Analytical Methods

Chase, P. (2017). *Trace elements analysis in some medicinal plants using graphite furnace-atomic absorption spectroscopy*. *September 2016*. https://doi.org/10.4491/eer.2016.007

Corwin, D. L., & Lesch, S. M. (2005). *Apparent soil electrical conductivity measurements in agriculture*. *46*, 11–43. https://doi.org/10.1016/j.compag.2004.10.005

Corwin, D. L., & Yemoto, K. (2019). *Measurement of Soil Salinity: Electrical Conductivity and Total Dissolved Solids*. *June 2018*. https://doi.org/10.2136/sssaj2018.06.0221

Dartey, E. (2015). *Determination of selected heavy metals contamination in water from downstream of the Volta Lake at Manya Krobo district in eastern region of Ghana*. *2*(November), 167–173.

Dartey, E., & Sarpong, K. (2016). *Association between Soil and Blood Lead Levels of Small Scale Battery Repair Workers in Kumasi Metropolis of Ghana*. *6*, 75–80. https://doi.org/10.5963/IJEP0601006

Del, V., Ijeh, I. I., & Ejike, C. E. C. C. (2015). *Current perspectives on the medicinal potentials of*. *April 2011*.

Dubey, S., & Kashyap, P. (2016). *Azadirachta indica : A Plant With Versatile Potential*. *January*. https://doi.org/10.5530/rjps.2014.2.2

Eng, S. J. (2020). *Determination Of Mineral And Trace Element in Some medicinal plants*. *38*(4), 2133–2144.

Fathabad, A., Shariatifar, N., & Ehsani, A. (2015). *Evaluation of toxic metals in canned fish market in Tehran*. *6*(05), 818–822.

Forstner U, Ahlf W, Calmano W (1993). Sediment quality objectives and criteria development in Germany. Water Science and Technology. 28:307

Ghana Statistical Service (2021). Ghana 2021 Population and Housing Census. Population of regions and districts. http://ghanadistricts.com , Volume 3A

Gyamfi, O., Aboko, J., Ankapong, E., Marfo, J. T., Awuah-boateng, Y., Agyei, V., Sarpong, K., Dartey, E., (2023). *Heavy metals in local and imported cosmetics in Ghana and their health risk assessment*. *Cogent Public Health*, *10*(1). https://doi.org/10.1080/27707571.2023.2217693

Haynes, R. J., & Naidu, R. (1998). *Influence of lime , fertilizer and manure applications on soil organic matter content and soil physical conditions : a review*. 123–137.

Heiniger, R. W., Mcbride, R. G., & Clay, D. E. (2003). *Using Soil Electrical Conductivity to Improve Nutrient Management*. 508–519.

Iruoghene, G., Oghenekeno, P., Ngukuran, A., Ogheneoruese, F., Ishioma, L., Obasohan, P., Rapheal, A., Electric, J., Ovie, V., Favour, C., Ugbuwe, E., Ongulu, J., Ijide, M., Destiny, I., Ruth, S., & Ewomazino, J. (2023). Biological and bioactive components of bitter leaf (Vernonia amygdalina leaf): Insight on health and nutritional benefits . A review. *Food Chemistry Advances*, *3*(October), 100488.

https://doi.org/10.1016/j.focha.2023.100488

Ishaq, S., & Jafri, L. (2017). *Biomedical Importance of Cocoa (Theobroma cacao): Significance and Potential for the Maintenance of Human Health Contents List available at RAZI Publishing Biomedical Importance of Cocoa (Theobroma cacao): Significance and Potential for the Maintenance of Human Health Matrix Science Pharma (MSP). January*. https://doi.org/10.26480/msp.01.2017.01.05

Karahan, F. (2023). Evaluation of Trace Element and Heavy Metal Levels of Some Ethnobotanically Important Medicinal Plants Used as Remedies in Southern Turkey in Terms of Human Health Risk. *Biological Trace Element Research*, 493–513. https://doi.org/10.1007/s12011-022-03299-z

Khuda, F., Iqbal, Z., Khan, A., Nasir, F., Muhammad, N., Khan, J. A., & Khan, M. S. (2010). *Metal analysis , phytotoxic , insecticidal and cytotoxic activities of selected medicinal plants of Khyber Pakhtunkhwa*. 51–58.

Konieczynski, P., Gappa, M., Wesolowski, M., & Pinto, E. (2022). *Trace Elements in Medicinal Plants Traditionally Used in the Treatment of Diabetes — Do They Have a Role in the Claimed Therapeutic Effect ?*

Kortei, N. K., Koryo-dabrah, A., Akonor, P. T., Yaw, N., Manaphraim, B., Ayim-akonor, M., Boadi, N. O., Essuman, E. K., & Tettey, C. (2020). *Potential health risk assessment of toxic metals contamination in clay eaten as pica (geophagia) among pregnant women of Ho in the Volta Region of Ghana*. *4*, 1–7.

Length, F. (2014). *Phytochemical screening and antibacterial evaluation of the leaf and root extracts of Cassia alata Linn*. *2*(7), 124–129.

Lokhande, B. R. S., Singare, P. U., Andhele, M. L., Acharya, R., Nair, A. G. C., & Reddy, A. V. R. (2009). *Study of some Ayurvedic Indian medicinal plants for the essential trace elemental contents by instrumental neutron activation analysis and atomic absorption spectroscopy techniques*. *331*, 325–331. https://doi.org/10.1524/ract.2009.1621

Lokhande, R. S., Andhale, M. L., & Singare, P. U. (2010). *INAA and AAS study of essential trace elements in ayurvedic Indian medicinal plants*. *1*(2), 150–162.

Lokhande, R. S., Singare, P. U., & Andhele, M. L. (2010). *Analysis of Trace Elements in Some Medicinal Plants by NAA and AAS Techniques 1*. *52*(3), 310–314. https://doi.org/10.1134/S106636221003015X

Lokhande, R., Singare, P., & Andhale, M. (2010). *Study on Mineral content of Some*

Ayurvedic Indian Medicinal Plants by Instrumental Neutron Activation Analysis and AAS Techniques. *3*, 150–161.

Macrostachyus, C. (2015). *Levels Of Major And Trace Metals In The Leaves And Infusions of Manganese ; CASRN 7439-96-5*. (1995). 1–46.

Mali Rohit P., Rao Priya S. and Jadhav R. S. (2019). *A Review on Pharmacological Activities of Calotropis Procera. Journal of Drug Delivery & Therapeutics*. 2019; 9(3-s):947-951

Meena, A. K., Yadav, A. K., Niranjan, U. S., Singh, B., Nagariya, A. K., Sharma, K., Gaurav, A., & Sharma, S. (2010). *A review on Calotropis procera Linn and its Ethnobotany , Phytochemical , Pharmacological profile Review Article A review on Calotropis procera Linn and its Ethnobotany , Phytochemical , Pharmacological profile*. *February 2019*.

Miholova, D., Langrova, I., & Tlustos, P. (2015). *Bioaccessibility versus Bioavailability of Essential (Cu, Fe, Mn, and Zn) and Toxic (Pb) Elements from Phyto Hyperaccumulator Pistia stratiotes : Potential Risk of Dietary Intake*. https://doi.org/10.1021/jf5058099

Mishra, M., Kumar, U., Mishra, P. K., & Prakash, V. (2010). *Efficiency of Plant Growth Promoting Rhizobacteria for the Enhancement of Cicer arietinum L . Growth and Germination under Salinity Efficiency of Plant Growth Promoting Rhizobacteria for the Enhancement of Cicer arietinum L . Growth and Germination under Salinity*. *January*, 1–6.

Mondal, E., & Chakraborty, K. (2016). *Azadirachta indica - A Tree With Multifaceted Applications : An Overview*. *June*.

Nadu, T. (2018). *Pharmacognostical and phytochemical evaluation of Cassia alata Linn*. *6*(5), 69–77.

Neina, D. (2019). *The Role of Soil pH in Plant Nutrition and Soil Remediation*. *2019*(3). https://doi.org/10.1155/2019/5794869

Nkansah, M. A., Korankye, M., Darko, G., & Dodd, M. (2016). Heavy Metal Content and Potential Health Risk of Geophagic White Clay from. *Toxicology Reports*, *August*. https://doi.org/10.1016/j.toxrep.2016.08.005

Njenga, I.K. (2017). *Analysis Of Essential Trace Elements In Selected Medicinal Plants Used In Kenya Njenga Isaac Kariuki B . Ed (Sc .) A Thesis Submitted in Partial Fulfilment of the Requirement for the Award of the Degree of Master of Science in Applied Analytical*

Chemistry in the School of Pure and Applied Sciences of Kenyatta University JULY , 2017.

Obeid, P., Saliba, C., Younis, M., … S. A.-W. T. on, & 2013, undefined. (2013). Comparative analysis of lead and cadmium levels in various brands of canned and processed meat products in Lebanon. *Witpress.Com*, *170*, 1743–3541. https://doi.org/10.2495/FENV130131

Odoemelam, V. (2021). *The Growing Importance of Neem Azadirachtaindica A . Juss) In Agriculture , Industry , Medicine and Environment A Review . September*.

Ogbonna, C. E., Adinna, E. N., & Chinyere, O. (2013). *Heavy metal concentration and physicochemical properties of soil in the lead- zinc mining area of Ishiagu , Nigeria Heavy metal concentration and physicochemical properties of soil in the lead-zinc mining area of Ishiagu , Nigeria Department of Environmental Resource Management , Abia State University , Uturu , Nigeria*. *October*.

Ogidi, O. I., George, D. G., & Esie, N. G. (2019). *Ethnopharmacological properties of Vernonia amygdalina (Bitter Leave) medicinal plant*. *7*(2), 175–181.

Ojezele, O. J., Okparaocha, F. J., Oyeleke, P. O., & Agboola, H. I. (2021). Quantification of Some Metals in Commonly Consumed Canned Foods in South-west Nigeria: Probable Pointer to Metal Toxicity. *Journal of Applied Sciences and Environmental Management*, *25*(8), 1519–1525. https://doi.org/10.4314/jasem.v25i8.36

Ojimelukwe, P. C., & Amaechi, N. (2019). *Composition of Vernoniaamygdalina and its Potential Health Benefits*. *6*, 1836–1848.

Ojo, I. O., Ojo, J. O., & Oladele, O. (2015). *Analysis of Heavy Metals and Some Physicochemical Parameters in Soil of Major Industrial Dumpsites in Akure Township , Ondo State of South Western Nigeria*. *7*(1), 55–61. https://doi.org/10.5539/ijc.v7n1p55

Owen, T., Field, J., Sindy, L., Kokatha, A. P., Birgitta, S., Adelle, C.F. C. (2019). *Ancient starch analysis of grinding stones from Kokatha Country, South Australia. Journal of Archaeological Science Reports 23 (2019) 178–188.* https://doi.org/10.1016/j.jasrep.2018.10.023

Online, G. (2013). *Izuka, C.M and Mbagwu, F.N Department of Plant Science and Biotechnology, Imo State University, Owerri, Nigeria*.

Print, I., Online, I., Meenupriya, J., Vinisha, A. S., & Priya, P. (2014). *World Journal of Pharmaceutical Sciences Cassia alata and Cassia auriculata – Review of their bioactive potential*.

Qasemi, M., Shams, M., Sajjadi, S. A., Farhang, M., & Erfanpoor, S. (2019). *Cadmium in*

Groundwater Consumed in the Rural Areas of Gonabad and Bajestan , Iran : Occurrence and Health Risk Assessment.

Quazi, S., Mathur, K., & Arora, S. (2013). *Calotropis procera: an overview of its phytochemistry and pharmacology*. *1*(2), 63–69.

Rahimi, E., Hajisalehi, M., Kazemeini, H. R., Chakeri, A., Derakhshesh, M., Mirdamadi, M., Ebadi, A. G., Rezvani, A., & Kashkahi, M. F. (2010). *Analysis and determination of mercury , cadmium and lead in canned tuna fish marketed in Iran*. *9*(31), 4938–4941.

Ranjit, P. M. (2014). *An Overview Of Phytochemical And Pharmacological Activities An Overview Of Phytochemical And Pharmacological Activities Of*. *January 2012*.

Reth, S., Reichstein, M., & Falge, E. (2014). *The effect of soil water content , soil temperature , soil pH-value and the root mass on soil CO2 efflux – A modified model The effect of soil water content , soil temperature , soil pH-value and the root mass on soil CO 2 efflux – A modified model*. *July*. https://doi.org/10.1007/s11104-005-0175-5

Rezapour, S., Damalas, C. A., Atashpaz, B., Moghaddam, S. S., & Kalavrouziotis, I. K. (2023). *Chemosphere Cadmium accumulation , translocation factor , and health risk potential in a wastewater-irrigated soil-wheat (Triticum aestivum L .) system*. *231*(September 2019), 1–7.

Rhoades, J. D. (1996). *Chapter 14 Salinity : Electrical Conductivity and Total Dissolved Solids*. *5*, 417–435. https://doi.org/10.7454/mss.v21i2.7309

S, R. P., & Jadhav, R. S. (2019). *A Review on Pharmacological Activities of Calotropis Procera*. *9*, 947–951.

Sadhu, A., Upadhyay, P., Singh, P. K., & Agrawal, A. (2015). *Quantitative analysis of heavy metals in medicinal plants collected from environmentally diverse locations in India for use in a novel phytopharmaceutical product*. https://doi.org/10.1007/s10661-015-4764-3

Sarpong, K., Asare, E. A., Dartey, E., & Effah-yeboah, E. (2022). *Heavy Metal Contents And Associated Health Risk Of Some Ghanaian And Asian Herbal Drugs*. *13*(March). https://doi.org/10.13040/IJPSR.0975-8232.13(3).1383-92

Sarpong, K., & Dartey, E. (2017). *Assessment of hazardous metal load in soils and medicinal plants samples from Suame Magazine , Kumasi*. *6*(6), 355–362.

Shinwari, Z. K. (2010). *Medicinal plants research in Pakistan*. *4*(3), 161–176. *A Review*. 26098–26100. https://doi.org/10.26717/BJSTR.2021.33.005446

Singare, P. U., & Talpade, M. S. (2013). *Study on toxic heavy metals in Indian Carp (C . catla) and vegetation of Bhavan ' s College Lake of Andheri , Mumbai*. *14*(1), 59–68.

Singh, S. K., Singh, C. M., & Lal, G. M. (2011). *Assessment of genetic variability for yield and its component characters in rice (Oryza sativa L .)*. *1*(4), 73–76.

Sobhan Rezayati, Ghazaleh Dinmohammadi, Ali Ramazani & Sami Sajjadifar (2022): *Mortar–Pestle Grinding Technique as an Efficient and Green Method Accelerates the Tandem Knoevenagel–Michael Cyclocondensation Reaction in the Presence of Ethylenediamine Immobilized on the Magnetite Nanoparticles, Polycyclic Aromatic Compounds,* DOI: 10.1080/10406638.2022.211050

Solomon, N., Adherr, K., Dartey, E., Dwumfour-, B., Asare, E. A., Sarpong, K., (2022). Effect of smoking and chargrilling on toxic metal (loid) levels in tilapia from the Afram Arm of the Volta Lake. *Environmental Pollutants and Bioavailability, 34*(1), 136–145. https://doi.org/10.1080/26395940.2022.2062453

Srinivasan, N. (2018). *Pharmacognostical and phytochemical evaluation of Cassia alata Linn*. Journal of Medicinal Plants Studies 2018; 6(5): 69-77

Takarina, N. D., & Pin, T. G. (2017). *Bioconcentration Factor (BCF) and Translocation Factor (TF) of Heavy Metals in Mangrove Trees of Blanakan Fish Farm*. *21*(2), 77–81. https://doi.org/10.7454/mss.v21i2.7308

WHO, (1992). Expert committee on specification for pharmaceuticals preparation. WHO technical report series 823, Report Geneva WHO 3, pp 44-52 and 75-76.

WHO (2009) The use of herbal medicine in primary health care. WHO technical report series 243, Report Geneva WHO 7, pp 26-33

WHO (2013) World Health Organization traditional medicine strategy: 2014-2023. World Health Organizition, 1211 Geneva 27, Switzerland.

WHO/FAO. (2021). Codex alimentarius commission. Food additives and contaminants. Joint FAO/WHO Food Standards Programme, ALINORM 95/12A.

Wuana, R. A., & Okieimen, F. E. (2011). *Heavy Metals in Contaminated Soils : A Review of Sources , Chemistry , Risks and Best Available Strategies for Remediation*. *2011*. https://doi.org/10.5402/2011/402647

Yeap, S. K., Ho, W. Y., Beh, B. K., Liang, W. S., Ky, H., Hadi, A., Yousr, N., & Alitheen, N. B. (2010). *ethnomedical used green vegetable with multiple bio- activities*. *4*(25), 2787–2812.

Yembeau, N. L., Biapa, P. C. N., Chetcha, B., Nguelewou, F. L., Kengne, F., Nkwikeu, P. J. N., Telefo, P. B., & Pieme, C. A. (2018). *In vitro Evaluation of Antioxidant and Anti-*

sickling properties of Theobroma Caca o (Sterculiaceae) extracts from East and South regions in Cameroon. *1*(1), 1–9.

Zhang, M., Liu, Z., Wang, H., Zhang, M., Liu, Z., & Wang, H. U. O. (2017). *Communications in Soil Science and Plant Analysis Use of Single Extraction Methods to Predict Bioavailability of Heavy Metals in Polluted Soils to Rice Use of Single Extraction Methods to Predict Bioavailability of Heavy Metals in Polluted Soils to Rice*. *3624*(February). https://doi.org/10.1080/00103621003592341

APPENDICES

Appendix 1. Descriptive Statistics of leaves of medicinal plants taken through SG

	CONC				
	Cd	**Cu**	**Mn**	**Pb**	**Zn**
Mean	0.02	0.47	0.27	0.22	0.71
Std. Deviation	2.28e-3	0.23	0.10	0.18	0.15
Coefficient of variation	0.15	0.50	0.37	0.82	0.21
Minimum	0.01	0.14	0.14	2.00e-3	0.49
Maximum	0.02	0.74	0.40	0.42	0.84

Appendix 2. Descriptive Statistics of leaves of medicinal plants taken through BG

	CONC				
	Cd	**Cu**	**Mn**	**Pb**	**Zn**
Mean	0.02	0.43	0.28	0.24	0.63
Std. Deviation	4.66e-3	0.22	0.15	0.23	0.19
Minimum	0.01	0.08	0.15	0.03	0.37
Maximum	0.02	0.69	0.53	0.54	0.87

Appendix 3. Descriptive Statistics of leaves of medicinal plants taken through MPG

	CONC				
	Cd	**Cu**	**Mn**	**Pb**	**Zn**
Mean	0.02	0.46	0.25	0.21	0.62
Std. Deviation	2.97e-3	0.23	0.09	0.19	0.12
Minimum	0.01	0.11	0.17	1.00e-3	0.42
Maximum	0.02	0.74	0.39	0.43	0.71

Appendix 4. Descriptive Statistics of roots of medicinal plants taken through SG

	CONC				
	Cd	**Cu**	**Mn**	**Pb**	**Zn**

Appendix 3. Descriptive Statistics of leaves of medicinal plants taken through MPG

	CONC				
	Cd	Cu	Mn	Pb	Zn
Mean	0.04	0.55	0.52	0.52	0.37
Std. Deviation	0.02	0.24	0.34	0.29	0.18
Minimum	9.00e-3	0.32	0.13	0.05	0.08
Maximum	0.04	0.74	0.87	0.70	0.54

Appendix 5. Descriptive Statistics of roots of medicinal plants taken through BG

	Concentration				
	Cd	Cu	Mn	Pb	Zn
Mean	0.03	0.51	0.40	0.37	0.54
Std. Deviation	0.02	0.23	0.27	0.27	0.24
Minimum	0.01	0.14	0.14	2.0e-3	0.20
Maximum	0.07	0.78	0.98	0.73	0.84

Appendix 6. Descriptive Statistics of roots medicinal plants taken through MPG

	CONC				
	Cd	**Cu**	**Mn**	**Pb**	**Zn**
Mean	0.02	0.47	0.34	0.30	0.48
Std. Deviation	0.01	0.25	0.23	0.23	0.18
Minimum	6.00e-3	0.04	0.12	0.001	0.17
Maximum	0.04	0.79	0.85	0.70	0.71

Appendix 7. Descriptive Statistics of plant mean concentrations (mg/kg)

Metal	Mean conc in Roots	Mean conc in Leaves	Mean conc in whole plant	P- value
Pb	0.494	0.321	0.408	0.021
Zn	0.332	0.589	0.461	0.052
Cu	0.623	0.449	0.536	0.118
Cd	0.024	0.014	0.019	0.218
Mn	0.419	0.293	0.356	0.153

Appendix 8. The recovery (%) of heavy metals in plants

Metal	**Spiked analyte concentration (mg/kg)**	**Calculated analyte concentration (mg/kg)**	**% Recovery**
Pb	0.25	0.24	95.60
Cu	0.50	0.51	102.00
Cd	0.50	0.46	92.00
Zn	0.75	0.72	96.00
Mn	2.50	2.37	94.80

Appendix 9. Significance test of metal concentrations analyzed for Translocation factor, Bioaccumulation coefficient and Bio concentration factor

	P - values		
Metal	**TF**	**BAC**	**BCF**
Pb	0.070	0.031	0.014
Zn	0.082	0.082	0.082
Cu	0.023	0.014	0.031
Cd	0.014	0.123	0.123
Mn	0.123	0.233	0.233