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MAMPONG – ASHANTI

HEAVY METAL DYNAMICS IN SELECTED DUMPSITE SOILS AND LETTUCE IN KUMASI AND MAMPONG IN THE ASHANTI REGION, GHANA

BY

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ABSTRACT

An arable land with wastes attracts backyard farming. Metals level in farmlands in and around dumpsite are health threat to the consuming public. Cu and Pb metals were assessed in soils in pots under field conditions with soils sampled from selected dumpsites and background sites in Kumasi and Mampong, in the Ashanti region of Ghana. Sample were assessed using a Niton XL3t GOLD field portable X-ray fluorescence spectrometer. Soil physicochemical properties in dumpsites soil were in improved levels than in backgrounds soil in pots. This study generally found Cu and Pb higher in dumpsites soil than in background soils. Pollution indices (Igeo and TR) indicated very high contamination for Cu in the dumpsites studied in the increasing order of contamination as Ayeduasu is greater Kyafasu but less than Suame (KYE < AYE < SUA).

Keywords: Pollution indices, XRF, Geo-accumulation Index, Enrichment Factor, Relative Top soil Enrichment Factor, Translocation Factor

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the study

The exponential growth in population, coupled with other issues associated with growing economies has posed a significant stress on the environment (Ahlijay, 2015) especially pressure on land for farming and other urban infrastructure and services (Owusu-Sekyere *et al.*, 2013). Dumpsites in Ghana are usually turned into other land uses such as crop cultivation, while some are excavated for soil amendment because of the rich mineral and organic matter (Akanchise *et al.*, 2020) which are known to be rich in soil nutrients for plant growth (Ogunyemi *et al.*, 2003).

Soil fertility challenges in Ashanti region of Ghana coupled with comparatively high cost of chemical fertilizers have all contributed in making dumpsites a cheap source of soil nutrient for backyard farmers as nutrient rich growth medium. Owusu- Sekyere *et al.* (2013) and Mwingyine (2008) have found that dumpsites are commonly used for direct cultivation of vegetables and also as good source of compost to support mainland agricultural activities because in most third world countries, dumpsite soils comprise of higher proportion (50 - 90 %) of organic matter materials (Asomani - Boateng and Murray, 1999). Currently, considerable pollutions from refuse disposal activities of man have introduced heavy metals into the soil environment which are of great ecological significance due to their toxicity at certain concentrations, translocation through food chains and their non - biodegradable nature resulting to their accumulation in the biosphere (Aekola *et al.*, 2008). Human electronic waste materials on dumpsites such as plastics, paper, metal rubbish and batteries which are known to be sources of heavy metals are hazardous to man and his environment (Alloway and Ayres, 1997; Pasquini and Alexander, 2004; Woodbury, 2005). Heavy metals are non - biodegradable, can undergo global ecological circles (Aekola *et al.*, 2008) and have toxic effects on living organisms at certain levels of concentrations.

Plants available nutrients in the soil solution may also be found in soils polluted with municipal, domestic or industrial wastes which may be bio accumulated in roots, stems, fruits, grains and leaves of the crops (Fatoki, 2000) or in the form of mobile ions present in the soil or through foliar absorption (Opaluwa *et al.*, 2012), before finally finding their way into human food chain.

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Agbeshie *et al.* (2020) conducted a study in Sunyani municipality to determine the risk of heavy metal pollution and physicochemical properties of soils (0-30cm) at a waste dumpsite, and found that the soil at the dumpsite is heavily contaminated with Fe (< 30 mgkg $^{-1}$) but was within the permissible limits recommended by FAO / WHO (2001). Agbeshie *et al.* (2020) used geoaccumulation index (I_{geo}) assessment module and found that, dumpsites soil studied were moderately to strongly contaminated with heavy metals. Akanchise *et al.* (2020) studied on the distribution of heavy metals in soils from abandoned dump sites in Kumasi, Ghana and found that, there were moderate concentrations of heavy metals (Cu, Pb) in dump site soils at Amakom and Kronum with few of the metal concentrations exceeding international soil quality guidelines but geoaccumulation index showed generally no pollution.

Studies by Agyarko *et al*. (2010) at Accra, Kumasi, Mampong and rural community dumpsite soils found that, the levels of leads in plants from the refuse dump soils in Accra, Kumasi and Asante Mampong were beyond the normal ranges of 40 - 500 ug g^{-1} (Pb) and 0.02 - 5.00 ug g^{-1} . Stewart *et al*. (1974) shared a similar view. Plants on polluted soils absorb heavy metals in the form of free moving ions in the soil through plants xylem and phloem vessels where they are bi-accumulated in their leaves, stem, fruits, grains and the root of the plant (Adebiyi *et al.*, 2018). However, a higher concentration of heavy metals in the soil can result in higher level of uptake by the plants (Ebong *et al.*, 2008). Critically examining dumpsites soil, backgrounds soil and plants found on them and their safety levels in crops which are in high demand for human consumption in Ghana may go a long way to help especially the consuming public.

The use of soils around dumpsites in rural and urban areas in Ghana is common for food production especially vegetables (Abgeshie *et al.*, 2020). Even the abandoned or closed dumpsites are usually turned into other land uses such as crop cultivation in addition to its use as soil amendment because of the rich mineral and organic content (Akanchise *et al*., 2020). However, most people use dumpsite soils without knowledge of the risk of heavy metal uptake by plants (Abgeshie *et al.*, 2020). The accumulation of excess amounts of metals contaminants in the environment threatens the health of plants and animals because metals exert biological effects on all life forms (Luo *et al.*, 2012; Cai *et al.*, 2015).

The evaluation of heavy metal contamination is an important component of risk assessment at waste dumpsites (Agbeshie *et al.,* 2020), an affirmation that dumpsites soil assessment for the concentration levels of some hazardous metals in addition to minimizing the accumulation of toxic metals in the food chain is necessary for healthy crop production in Ghana. This study was undertaken to comparatively assessed the concentration of heavy metals (Cu and Pb) in soils from Kyeremfaso Mampong dumpsites soil (KYE), University of Education Winneba, Mampong background soil (UEW), Suame Kumasi dumpsite soil (SUA), Meduma Kumasi background soil (MED), Ayeduase Kumasi dumpsite soil (AYE) and KNUST botanical gardens (KNUST) in the Mampong Municipal and Kumasi Metropolis in the Ashanti region of Ghana.

1.2 Problem Statement

The use of soils around dumpsites in rural and urban areas in Ghana is common for food production especially vegetables (Abgeshie *et al*., 2020). According to Akanchise *et al*. (2020), abandoned dumpsites are usually turned into other land uses such as crop cultivation in addition to its use as soil amendment because of the rich mineral and organic content. However, most people use dumpsite soils without knowledge of the risk of heavy metal uptake by plants (Abgeshie *et al*., 2020). The accumulation of excess amounts of metals contaminants in the environment threatens the health of plants and animals because metals exert biological effects on all life forms (Luo *et al*., 2012; Cai *et al*., 2015). Backyard farming on dumpsite soils in the Ashanti region of Ghana is gaining popularity due to the fact that some of these wastes provide nutrients for healthy and increased plant growth and such positive effect encourages continued backyard farming on dumpsite soils.

The evaluation of heavy metal contamination is an important component of risk assessment at waste dumpsites (Agbeshie *et al.,* 2020), an affirmation that dumpsites soil assessment for the

concentration levels of some hazardous metals in addition to minimizing the accumulation of toxic metals in the food chain is necessary for healthy crop production in Ghana.

1.3 Significance of the Study

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1.4 Limitations of the Study

1.5 Research Objectives

The main objective of the study was to comparatively, assess the concentration levels of selected heavy metals in dumpsites and background soils and plants in selected urban and rural dumpsites in the Ashanti Region of Ghana. The specific objectives are to:

1. Determine the level of copper and lead in lettuce grown in Kumasi and Mampong dump site soils.
2. Determine the physiochemical properties of dump site soils from Kumasi and Mampong
3. Assess the pollution level of copper and lead in selected dump site soils in Kumasi and Mampong.

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CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Waste Dumpsite Soils

A waste dumpsite is where waste materials are disposed of and is the oldest form of waste management (Ibrahim *et al*., 2013) in Ghana. Waste dumpsite contains high concentrations of heavy metals and are later absorbed and accumulated by the plants growing within such sites (Hammed *et al*., 2017) more than their counter parts found on normal agricultural soils in Ghana, most among them are vegetables which are the most exposed food crops to environmental pollution due to aerial burden (Jolly *et al*., 2013). In modern times, pollutions from the activities of human have introduced some of these heavy metals into the ecosystem (Opaluwa *et al*., 2012) while others occur naturally in the ecosystem with large variations in concentrations. However, they may occur naturally in low concentration and are found to be toxic even at low concentrations (Dinis and Filiza, 2011). When these metals slowly accumulate and distribute in the soil profiles over time, the soil can act as a long term sink for these toxic metals (Amesaki, 2018).

Dumpsite soils contain heavy metals such as copper (Cu) and lead (Pb *et al*., 2018), which persist and accumulate over a long time in soils and vegetations and thus resulting to serious environmental pollution (Mtunzi *et al*., 2015). Many areas near urban centres where wastes are dumped contain high concentrations of heavy metals in their ecosystem (Adelekan and Abegunde, 2011) and their deposits in the soil are not degraded and may persist in the soil environment for a long time causing serious environmental pollution (Oyelola, 2009). In these dumpsites, heavy metals such as Copper (Cu) and lead (Pb), are usually found due to remains from metals and other

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products (Shayley *et al*., 2009) and the plants grown on them have the tendency of taking metals (Orji *et al*., 2018). The dumpsite wastes contain heavy metals so their presence and subsequent uptake by food crops can pose serious human health risk (Darko *et al.,* 2020).

The distribution of heavy metals on waste dumpsite soils in Ghana is related to the population of the rural and urban dwellers, their standard of living, consumption pattern and industrial development. Agyarko *et al*. (2010) studies in Accra, Kumasi and Adidwan where refuse dump soils varied in concentrations of most metals like Cu, Pb,and attributed those differences in concentration to the fact that, metals found in the cities (Accra and Kumasi) and a municipal (Mampong) were higher than those from Adidwan - a rural settlement due to the higher population and industrial activities in cities and municipalities coupled with higher level of assorted waste than in rural settlement. Ebong *et al*. (2008) shared a similar view by attributing such differences to living standard, consumption patterns and level of industrial development between cities and rural communities. Bamidele *et al.* (2014) have also asserted to the fact that differences in physical and chemical properties of soils within dumpsites and background sites might be due to economic activities of the people within the rural, urban towns and cities. Metals like Cu and Pb found in such rural and urban wastes (Sule *et al*., 2019) are critical measurement parameters for assessing the risks of refuse dump soils (Hammed *et al.,* 2017) especially metal accumulation at the top soil (Moses, 2006) which if not checked can cause a more widespread contamination of soil, sediments and vegetables (Jafaru *et al*., 2015). Generally, top soil layer contains the largest amount of pollutants (Addis and Abebaw, 2017).

2.1.1 Uses of Dumpsite Soils

The soil which is a primary recipient of solid wastes (Nyle and Ray, 1999) receives tonnes of these wastes from industrial, domestic and agricultural sources (Ogunmodede and Adewole, 2015). These wastes end up interacting with the soil system changing their physical and chemical properties (Piccolo and Mbagwu, 1997), especially soil organic matter in dumpsites help to influence the degree of aggregation and aggregate stability by reducing soil bulk density and increasing soil total porosity and hydraulic conductivity in heavy clay soils (Ogunmodede and Adewole, 2015).

Soils found on dumpsites, sites for disposal of waste materials (Musa *et al*., 2019) are used as farmlands and is a common practice in urban and sub-urban communities within countries (Musa *et al*., 2019) such as Ghana because when some of these waste decay they enhance soil fertility (Ogunyemi *et al*., 2015). Akanchise *et al*. (2020) reported that, sometimes, soils from dumpsites are excavated for soil amendments elsewhere because of the rich mineral and organic content. However, a considerable proportions of plastics, papers, metals and batteries known to be hazardous to man and his environment are present on dumpsites (Pasquini and Alexander, 2004; Wood bury, 2005).

In Ghana dumpsite soils are commonly used for farming activities (Jafaru *et al*., 2015). Agyarko *et al.* (2015) reported in their study that plants on dumpsites perform better than those found in the surrounding areas. Dumpsite soils found to support plants growth also have the tendency to be taken up by plants (Orij *et al.*, 2018). The nutritional supports from dumpsites for plants affirms the reason why dumpsite soils are used in nursery pots for raising seedlings despite toxic metals contamination in them (Jafaru *et al.*, 2015) while other organic components from dumpsites are

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collected and apply on farmlands as manure by farmers (Ebong *et al.*, 2008). It is common to see crops grown around dumpsites despite the presence of heavy metals and their subsequent uptake by food crops can pose serious human health risk (Darko et al., 2020).

Heavy metal loads from refuse dump soils studied by Ogunmodede and Adewole (2015) reported to be higher in concentration than in the control (background) values especially for copper (Cu) and lead(Pb) and they attributed this to the fact that, refuse dumps receive considerable waste proportions of product packaging, waste cloths, glass and bottles, newspapers, paints, batteries, industrial dust, ash, tyre, metal cans and containers, medical waste, abandoned vehicles and insulations which are known to be sources of metals (Woodburry, 2005).

2.1.2 Physicochemical Properties of Dumpsite Soils

Soil physicochemical parameters like texture and organic matter contents are important with regards to the forms of heavy metals present and their bioavailability (Audinalp and Cresse, 2009). Heavy metals which form part of dumpsites soil chemical composition are metallic chemical elements that have relatively high density and are toxic at low concentrations (Ambika *et al.*, 2016). Dumpsites soils may also comprise of other materials that contain heavy metals and as a result are of great concern (Olakunle *et al*., 2018) to farmers and consumers in Ghana.

Soil which is one of the important natural resource which provides the main mineral elements for plant growth and crop production (Uma *et al*., 2016) is without contamination from waste materials found on them but on the contrary, essential mineral materials from these wastes also help to increase nitrogen, pH, CEC, Base saturation and organic matter (Anikwe and Nwobodo, 2001). Organic components of these wastes can provide nutrients for increased plant growth because, dumpsites are known to be rich in soil nutrient for plant growth and development

(Ogunmodede and Adewole, 2015) as decayed and composted wastes enhance soil fertility (Ogunyemi *et al*., 2003).

Organic matter influences the concentration of heavy metals in soil through the release of heavy metals such as Pb and Cuonded to organic matter in addition, there is a reduction in heavy metal levels in soils especially in the soil surface by forming complexes (Ashworth and Alloway, 2004). Most refuse dumpsites contain considerable amount of ash, and some of these ashes are dumped while others are produced from the burning of refuse on dumpsites from time to time to get rid of organic materials, and this activity help to oxidize the metals content (Nurudeen and Aderibigbe, 2013). Wastes end up interacting with the soil system thereby changing the physical and chemical properties (Piccole and Mbagwu, 1997). Soil organic matter has also been found by Ogunmodede and Adewole (2015) to influence the degree of aggregate stability, reduction in soil bulk density, increase soil total porosity and hydraulic conductivity in heavy clay soils. In an earlier study, the enhanced levels of lead (Pb) in dumpsites was attributed to large deposits of PVC plastic Cu batteries, insecticides, motor oil and the disposal of sewage in dumpsites (Jarup, 2003). Other chemical properties of dumpsites soil with respect to heavy metals were in these concentrations: Cu (1059.2 mgkg^{-1}) in sub-surface soils (15 – 30 cm) also comprise of control soils (uncontaminated soils) with Cu (665.3 mgkg^{-1}); Pb (99.1 mgkg^{-1} as reported by Ukpong *et al*. (2013). Dumpsite soils physicochemical properties play a major role in soil nutrition as they can be used as a nutrient rich soil indicator (Tripathi and Misra, 2012), because nearly all human activities generate waste; and the way in which wastes are handled and disposed of can pose risks to the environment and public health (Zhu *et al*., 2008).

On dumpsites, an organic matter which is an important soil chemical property was reported in a study by Tripathi and Misra (2012), to be at 0.39 – 0.58% as compared to their adjoining areas (0.32 – 0.58%) and attributed it to the presence of many organic waste residue which end up adding organic matter after decay and an inorganic waste will produce high bulk density in a dumpsite and may reduce root length and limit root penetration in a dump soil.

Tripathy and Misra (2012) found that, soil texture plays a very important role in plant species establishment and development and also influences other physical parameters of the soil. Another way which is beneficial to a dumpsites farmer is a situation where a dumpsites soil does not only accumulate organic matter but also results in a buildup of the soil organic matter content. Engege and Lemoha (2012) found that, dumpsite soil showed variability in soil properties with depth because there was a significant ($P \leq 0.05$) difference in heavy metal content, exchangeable cations, soil pH as well as bulk density with respect to soil depth.

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2.2 Assessment of dumpsites farmers' awareness of soil physicochemical knowledge

2.2.1 Socio - demography of farmers in Ghana

In Ghana, farming activities in some communities are dominated by males and majority of these farmers are below 51 years of age (Agyarko *et al.*, 2011) an indication that an active age group are actively involved in farming in Ghana. Other similar study has reported of a male (65%) dominated farming activity as compared to female (35%) minority with a youthful average age of 43 years in farming while the majority (77.8%) are educated up to the primary school level

(Dawoe *et al.*, 2012). A study has found that, farmers' knowledge of their soils was not influenced by their main source of income, gender, education and age (Sierra *et al.*, 2016).

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2.2.2 Reasons for farming on dumpsites

Soil is one of the most important resources of nature where plants grow for their day to day nutrient needs (Tale and Ingole, 2015). An assessment of the phenomenon of residential development close to a solid waste dumpsites at Pantang, found that farmers farm on dumpsites because, dumpsites land are fertile due to the decomposition of refuse (organic materials), other reason was that it is a way of protecting their lands from intrusion while other respondents said it is the only idle land available and renting a dumpsite land is relatively cheaper was also a reason (Ahlijah, 2015).

Wunzani *et al.* (2019) found that, soils from dumpsites are rich with plants micronutrients and macronutrients and those refuse dumps from dumpsites can be used as compost for soil amendment. Farmers especially in a developing country like Ghana, as observed by Monohara and Belagali (2014) that compost of solid wastes contain a considerable variety of micro and macro nutrients as well as relatively stable source of organic matter essential for plant growth. In addition, agricultural application of municipal solid wastes (MSW) as a natural source for plant and soil conditions is the most cost effective option (Bamidele *et al.*, 2014) for local farmers. Dumpsites are easily accessible land in addition to the perception that its high plant nutrient content are used up by crops planted as affirmed by Amadi *et al.* (2013) that, soils obtained from dumpsites are used for plantings of vegetables and food crops. Farmers in a developing country like Ghana have a local soil physicochemical knowledge in which site previously used as dumpsites are often converted to farmlands as observed by Onwughara *et al.* (2010).

2.2.3 Farmers' Awareness of Dumpsites Soil Physicochemical Properties

Farmers and Scientists understand soil fertility in different ways because scientists often only take account of the soil's nutrient status, without considering its physical properties but farmers' perception of soil fertility are not limited to nutrient status alone but also physical properties (Corbeels et al., 2000). An understanding of physical and chemical condition of any soil is essential for proper implementation of many management practices so the physicochemical idea of soil is very important because both physical and chemical properties affect the soil productivity example, this physico-chemical idea of a soil is based on various parameters like pH, electrical conductivity, texture, moisture, temperature, soil organic matter, available nitrogen, phosphorus and potassium (Tale and Ingole, 2015).

African farmers in the rural areas to whom development efforts are directed have their own body of knowledge that enables them arrive at decisions, which could help better their lots (Kolawole, 2002). African farmer's knowledge on a fertile soil can be likened to a modern concept of a quality soil which is the ability of a soil to sustain plant and animal productivity, to increase quality water and air and to contribute to plant and animal health (Doran and Zeiss, 2000). Farmers in Ethiopia in a similar study used a local system to classify their soils according to colour, texture and certaipln physical characteristics indicating that farmers are aware of their soils physicochemical properties (Corbeels et al., 2000).

The Ghanaian farmer know indigenous soil science with sets of information about the soils they farm on especially the fertility status of their soils by using crop yield, colour of soil, vegetation cover, soil depth, soil organic matter and activities of soil organisms (Agyarko *et al.*, 2011) as

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evidence of their soil physicochemical knowledge. In order to achieve high yield for their crops due to known and unknown reasons, farmers have resorted to farming on both open and closed dumpsites in Ghana and have proven to increase crop yield. However, the contamination levels of toxic metal elements in dumpsites farmlands have been given less attention to the detriment of healthier food production

In Ashanti region, a similar study reported that farmers have specific indicators they use for assessing their soils as fertile (high soil nutrient content) and infertile (low soil nutrient content) example, crop yield, dark soil colour, earthworms (fertile soil); slow plant growth pale soil colour, few worm casts (infertile soil) (Dawoe *et al.*, 2012).

2.2.3.1 Sources of Knowledge Acquisition on Soil Physicochemical Properties by Dumpsite Farmers

A bunch of studies have been found regarding farmers' preferences and use of information sources (Gupta and De, 2011; Sakib *et al.*, 2015; Rahman *et al.*, 2016) to maximise yield on their farmlands. Farouque *et al.* (2019) concluded in their studies that friends and neighbors play important role in disseminating farming information. Dumpsites farmers' perceived awareness of their soils' physicochemical properties are believed to have got their information from other sources as earlier asserted by De Souza *et al.* (2016) that soil properties information that farmers are familiar with are based on observation and life experience over time, which is accumulatively transmitted over generations.

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Farmers locally have acquired knowledge from generations of experience and experimentation that fit local conditions (Laekemariam *et al.*, 2017). Rehman *et al.* (2013) reported in their study that the print media and fellow farmers were the major information source to farmers. Sumane *et al.* (2017) shared a similar finding that, farmers are from farming families, so they obtain their initial agricultural knowledge from their parents, grandparents and other farmers due to the fact that, they see their colleague farmers a reputable experts, particularly due to their practical experience in similar conditions. Other knowledge acquisition for farmers is social networks regarding soil fertility issues and other farming information (Farouque *et al.*, 2019). Rydberg *et al.* (2008) have asserted that farmers can access information when frequently visit personal localite (e.g. friends) or cosmopolite (e.g. agriculture office).

2.2.4 Farmers' Awareness and Perceived Effects of Heavy Metals Contamination in Soils and Plants and its Related Ailments

Reported effects of heavy metals by farmers contamination in soils and lands can be related to measured common sources of soil contamination (hazardous heavy metals / metalloids) through atmospheric deposition, organic manure, mineral fertilizers, pesticides, industrial sewage discharge and industrial solid waste, municipal agriculture and food waste, coal ash, dumps, logging and timber industry waste paints and other decorative materials commodity impurities, etc (Nriagu and Payna 1988; Yongsheng, 2008; Zhang *et al.*, 2011, Allowey, 2012, Vodyganitskii, 2013, Su *et al.*, 2014). It is reported that about 61.33% of a community studied are aware of environmentally friendly agriculture can increase the growth, quality and productivity of agricultural land (Atmojo, 2010; Utari *et al.*, 2018) especially dumpsites farmlands.

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Pradika *et al.* (2019) concluded that people's awareness reportedly of heavy metal contaminations on agricultural land are still low people knowledge and awareness of heavy metals are still low a community is awareness about environmentally friendly agriculture is high (Atmojo, 2010). Coffie (2010) have found that due to the fact that landfill site contain dumpsite, high prevalence of infectious diseases like malaria, cholera, diarrhea, typhoid fever among others. At Dompoase dumpsites in the Kumasi Metropolis, within Ashanti region of Ghana, increased self-reported health symptoms such as fatigue, sleepless, and headaches were among residents near the landfill sites (Owusu-Sekyere *et al.,* 2013a)

2.3 Heavy Metals

Heavy metals are described as those metals with specific gravity higher of more than 5gcm^{-3} (Leah *et al*., 2014). Lenntech (2004) and Duruibe *et al.* (2007) have also explained that, heavy metals refer to any metallic element that has a relatively high density and is toxic or poisonous even at low concentration. Alamgir (2017) also defined heavy metals as any element that has a silvery luster and is a good conductor of heat and electricity. The most common of these metal elements are Copper, and lead,. Leah *et al*. (2014) have reported that, some elements such as iron and nickel are essential to the survival of all forms of life if they are low in concentrations, in addition to elements like lead, and cupper which are toxic to living organisms even in low concentrations.

Heavy metals have attracted much concern because of a lot of reasons. Considerable number of them, such as lead, and cupper are of concern primarily because they harm soil organisms, plants, animals and human beings (Adelekan and Alowode, 2011). The presence of heavy metals in the environment is of great ecological significant due to their toxicity at certain concentrations, translocation through food chains and non-biodegradation which is responsible for their accumulation in the biosphere (Aekola *et al*., 2008). Metals like copper, and lead occur naturally in the environment and could serve as plant nutrient on their concentrations (Opaluwa *et al*., 2012). Other metals like lead, and many others indirectly distributed as a result of human activities could be very toxic even at low concentrations and can undergo global ecological circles (Aekola *et al*., 2012).

The increasing ecological and global public health concerns about heavy metal contamination are not only exposed to soil and plants, but through human consumption of contaminated farm products, the use of heavy metals in several industries in agriculture, domestic and technological applications (Bradi, 2002). A study in Poland showed heavy metals concentration of Pb (12.5 – 659 mgkg^{-1} and Cu (12.9 - 595 mgkg^{-1}) in 180 allotment garden soils in Wroclaw, and these metals concentration levels depended mainly on the nearby location of industrial pollution sources, with variations in the amount of organic matter soil pH, and the content of plant available macronutrients (Kabala *et al*., 2009). Heavy metals occupy a special position in soil chemistry because they play very important physiological roles in nature (Akpoveta *et al*., 2010; Oves *et al*., 2016).

2.3.1 Sources of Heavy Metals in Dumpsite Soils

Heavy metals occur naturally in soils (Franzen *et al.*, 2004) and in the ecosystem with large variations in concentration. Heavy metals are not degradable, and as a result may persist and accumulate over a long period in soils and vegetation resulting in serious pollution of the soil environment (Mtunzi *et al.*, 2015). Dumpsite soils are perceived as fertile soils and a valuable asset which creates a congenial climate for crop production but due to human wastes disposal activities, dumpsite soils have become a receptor of many pollutants including pesticides, fertilizers, particulate matters and heavy metals (Maneyahilishal *et al*., 2018). However, if a soil's capacity to hold or retain heavy metals is exceeded, the soil begins to act as a source for heavy metals (Selim, 2013). The contamination of soils by different pollutants has significant influence on human health processes (Rhaman *et al*., 2015). Since heavy metals are not degradable, they persist and accumulate over a long period in the soils and vegetation resulting in serious environmental pollution (Mtunzi *et al*., 2015). Heavy metals occur in soils naturally (Franzen *et al*., 2004), in the ecosystem with large variations in concentration.

In modern times, pollutants from the activities of humans have introduced some of these heavy metals into the ecosystem (Opaluwa *et al*., 2012). They are also found to occur naturally in the soil environment from the pedogenetic processes of weathering of parent materials at levels that are regarded as trace (< 1000 mgkg^{-1}) and rarely toxic (Kabata – Pendias and Pendias, 2001; Pierzynski *et al*., 2002; Wuana and Okieimen, 2011)). A soil which most often than not suffers from these metal contaminants has been described by Nyle and Ray (1999), as a primary recipient of solid wastes. Tonnes of these wastes are from a variety of sources including: industry, domestic and agricultural activities which find their way into the soil (Ogunmodede and Adewole, 2015). Sources of soil metal contamination affecting predominantly agricultural soils include fertilizers, pesticides, sewage sludge, organic manures and composts (Singh, 2001). In addition, heavy metals accumulate in soils in some localized areas of human activities when compared with areas that have remained under virgin conditions. Some of the anomalous accumulation may also be geology – related (Thornton, 1980). Also, hazardous materials like plastics, papers, batteries, electric bulbs and bottle caps are known to contain heavy metals (Amusan *et al*., 2005; Akpoveta *et al*., 2011; Kolo *et al*., 2014) and similar materials are also found on dumpsites in Ghana. Some human activities such as waste disposal, mining, smelting and fertilizer applications also release heavy metals into the environment (Dinis and Fiuza, 2010; Ato *et al*., 2010). Other sources of heavy metals pollution have also been reported from compost application (Hogarh *et al*., 2008; Jordâo *et al*., 2006) and urban top soils (Darko *et al*., 2017).

The indiscriminate disposal of wastes (organic and inorganic) in rural and urban settlements coupled with farming on dumpsites soils pose risk to nature, and it is due to the fact that, most soils of rural and urban environments may accumulate one or more of the heavy metals above defined background values high enough to cause risks to human health plants, animals ecosystem or other media (D'Amore *et al*., 2005). It has been explained that, the reason why heavy metals become contaminated in the soil environment is that their rates of generation via man made cycles are more rapid relative to natural ones; the concentrations of the metals in discarded products are relatively high compared to those in the receiving environment (D'Amore *et al*., 2005). On most dumpsites, loads of contaminants that are usually greater than in the surrounding sub-urban or rural areas due to the concentration of anthropogenic activities of urban settlements (Charlesworth *et al*., 2003). It is estimated that heavy metals release from all sources worldwide is around (in metric tons) 22,000 of Cu, 939,000 of Pb (Singh *et al*., 2003).

2.3.1.1 Application of Metal - Based Pesticides and Fertilizers

Anthropogenic (human activity) materials such as pesticides and insecticides contaminate the soil environments with heavy metals like Cu and Pb but are also needed in metal elements deficient soils which help in healthy plant growth (Lasat, 2000). Crops may be supplied with metal elements in addition to the essential soil elements as a foliar spray, however, about 10% of the chemicals have approval for use as insecticides and fungicides in United Kingdom where they were based on

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compounds like Cu and Pb in pesticides such as copper containing fungicidal sprays such as Bordeaux mixture (copper sulphate) and copper oxychloride (Jones and Jarvis, 1981).

2.3.1.2 Application of Manures and Biosolids

Farmers in Ghana greatly use manures on their farmland, with the use of numerous biosolids like livestock manures, composts and municipal sewage sludge to land inadvertently leads to the accumulation of heavy metals such as Cu, Pb and others in the soil (Basta *et al*., 2005). Some of these heavy metals relative to their properties are used as growth promoters in animal nutrition but when used at high concentrations may cause metal contamination of soil in the long run (Summer 2000).

2.3.1.3 Air - Born Source

Soil heavy metal contaminants classified as air-born may include stack vapour stream and some fugitive emissions such as dust from waste piles (Raymond and Okieimen, 2011). Others sources of heavy metals contamination are atmospheric deposition, soil erosion of metal ions, leaching of heavy metals, sediments re-suspension, metal evaporation from water resources to soil and underground water, natural phenomenons such as weathering and volcanic eruptions have all contributed to heavy metal pollution (Bradi, 2002; Duffus, 2002; He *et al*., 2005).

2.3.1.4 Industrial Processes

Wastes are any discarded or abandoned materials that can be solid, liquid, or semi-solid and are always sourced from homes, schools, hospitals and other business areas (Buszewski *et al*., 2000). In addition, wastes disposed on sites through human activities in industry such as textiles tanning, petrochemicals from accidental oil spills or utilization of petroleum – based products and other

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pharmaceutical facilities are highly variable in composition although some are disposed off on land, and few have benefits to agriculture or forestry (Raymond and Okieimen, 2011). Many industrial products contain metals like Pb, and Cu which are potentially hazardous because of their contents are referred to as toxic inorganic compound contain lower plant essential nutrients and with no soil conditioning properties (Sumner, 2000). Other metal industrial sources include metal burning in power plants, petroleum combustion, nuclear power stations, high tension lines, plastics, textiles, microelectronic wood preservation and paper processing plants (Arruti *et al*., 2010; Pacyna, 1996). Electrical and electronic parts such as copper pipes and alloy from vehicle scraps littered for a long time on the soil gradually rust and leach into the soil causing phytotoxicity (Nwachuku *et al*., 2010).

2.3.2 Essential Heavy Metals

There are eighteen essential heavy metals out of fifty-three total heavy metals which are naturally occurring (Mistra, 2015). Essential heavy metals are needed in trace amounts by living things for their physiological processes (Ehi and Uzu, 2011). Plants usually need a continuous nutritional supply in order to remain healthy and any shortage leads to deficient symptoms (Oves *et al*., 2016). Metals which are essential to plants are required by plants to complete their life cycles. At higher concentrations, the essential heavy metals are hazardous to plants and animal (Ehi and Uzu, 2011), especially when Cu and Pb concentrations exceed the recommended standards (Afzal *et al*., 2013). WHO (1996) found that, metals like Cu and Pb perform various biochemical and physiological functions. These metals are considered as trace elements because of their presence in trace concentrations (ppb range to less than 10 ppm) in various environmental matrices (Kabata – Pendias *et al*., 2001).

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Plants in general need many different metals and other elements for growth, development and reproduction, but metals which are naturally present in the soil have increased in concentrations to pollution levels as a result of human activities ranging from mining and agriculture to sewage processing and heavy metal industry (Giovanni *et al*., 2014). Mengel *et al*. (2001) have earlier reported that, there are fourteen mineral elements which are essential to all plants in addition to water, oxygen and carbon dioxide. Metals like copper (Cu), lead (pb) help in regulating human metabolism (Lokeshappa *et al*., 2012). Most heavy metals are necessary for growth and normal functions of both plants and animals at trace amounts such as Cu and Pb but large amount of any of them may cause acute or chronic toxicity (Addis and Abebaw, 2017). Some essential metals serve as soil conditioners which are of great importance due to their universal medium which supply essential nutrients for plant growth (Pujar *et al*., 2012; Tripathi *et al*., 2015).

2.3.2.4 Copper (Cu)

Copper is an essential nutrient that play key roles in photosynthesis, respiration, carbon and nitrogen metabolism and protection against oxidative stress (Giovanni *et al*., 2014) and its addition is a necessity for many enzymes (Sha *et al*., 2013; Ngange *et al*., 2013) and as a macro nutrient for plants (Ngange *et al*., 2013).

Cu is used in numerous applications because of its physical properties (Hameed *et al*., 2013). In plants there are about 50 % of copper which is localized in the chloroplast (Banerjee, 2003). Cu is indeed essential, but in high doses can cause anaemia, liver and kidney damage (Wuana and Okienimen, 2011). The solubility of copper is drastically increased at pH 5.5 (Martinez and Motto, 2000). Cu normally accumulates in the surface horizons, a phenomenon explained by the bioaccumulation of the metal and recent anthropogenic sources (Hameed *et al*., 2013). the third

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most used metal in the world (Greany, 2005), an essential micronutrient like Cu is required in the growth of both plants and animals (Wuana and Okieimen, 2011).

The worlds' scale value of non-polluted soil of 24 mgkg^{-1} is reported by Kabata – Pendias and Pendias (2001) and though the toxicity for humans is not very high (Poggio, 2009), excess effects of copper on plants are reactive oxygen species (Seacat *et al*., 2002), stunted growth inhibition of lateral development (LIorens *et al*., 2002). In addition their excess results in photosynthesis inhibition (Patsikka *et al*., 2002; Maksymiec and Baszynski, 1999). High concentration of copper causes metal fumes fever, hair and skin discolorations, dermatitis, respiratory tract diseases and some other fatal diseases in human beings (Khan *et al*., 2008).

The permissible level of copper intake in food is 2 - 3 mgday^{-1} (WHO, 2005). Toxic levels are naturally present in some soils or may be derived from anthropogenic activities such as the use of copper containing fungicides, urban wastes management and industrial activity (Giovani *et al*., 2005). The mean value levels of copper concentration in plant tissue have been found to be 0.26 mgkg^{-1}, 0.37 mgkg^{-1} and 0.56 mgkg^{-1} for roots stems and leaves respectively while that of soil were 0.48 mgkg^{-1} (0 – 15 cm depth) and 0.32 mgkg^{-1} (15 – 30 cm depth) (Ngange *et al*., 2013)

2.3.3 Non – Essential Heavy Metals

The contamination of agricultural soils by metals has become an environmental concern due to their potential adverse ecological effects (Ngange *et al*., 2013). The Non-essential metals are considered as soil pollutants due to their acute and chronic toxic effect on plants grown on such soils (Nagajyoti *et al*., 2010). Metals like antimony (Sb), lead (Pb), have established biological functions and are considered as non-essential metals (Chang *et al*., 1996). The distribution and

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uptake of toxic nutrients within plants tissues according to their need for essential mineral nutrients in sufficient amount avoids the accumulation of non-essential elements and toxic levels of essential elements (Williams and Salt, 2009). This is due to the fact that, there exist a very narrow range of concentrations between beneficial and toxic effects of metals (Tchounwou *et al*., 2008).

2.3.3.4 Lead (Pb)

Lead is a non-essential metal element which is extremely toxic at low concentration (Shah *et al*., 2013). It can cause learning disabilities and hyperactivity in children (Hunt, 2003). It is known that lead containing dust particles take time in the atmosphere and deposit quickly in the near vicinity of the road, hence contributing to further accumulation of lead on the roadside soil surface (Al – Chalabi and Hawker, 2000). Pb has been shown to accumulate to high levels in urban environments from a range of sources including that derived from leaded petrol (Moller *et al*., 2000), calcium carbonate particles or in phosphate concentrations (Kabata – Pendias and Pendias, 2001).

The species of lead vary considerably with soil type; it is mainly associated with clay minerals, magnesium oxides, aluminum hydroxides and organic matter (Abdul – Hameed *et al*., 2013). The worlds' average Pb in unpolluted soil is 44.0 mgkg^{-1} (Kabata – Pendias and Pendias, 2001). Lead can enter the environment especially through numerous activities (mining, smelting and manufacturing) and can be toxic to human health (Poggio *et al*., 2009).

The most serious source of exposure to soil lead is through direct ingestion of contaminated soil or dust and as a result higher concentrations are more likely to be found in leafy vegetables and on surface of root crops (Wuana and Okieimen, 2011).

Rosen (2002) had earlier found that, soil lead levels above 300 mgkg^{-1} is from lead contaminated soil or dust deposits on the plants rather than from uptake of lead by plants. Generally, it has been considered safe to use garden produce grown in soils with total lead levels less than 300 mgkg^{-1} (Wuana and Okieimen, 2011). Further studies conducted by Kabata – Pendias (2011), also found that, the worlds' calculated average of lead on unpolluted soils has concentration level of 27.00 mgkg^{-1} and although lower than a value given by Onyedika (2015), in residential area (136.76 mgkg^{-1}); industrial area (159.67 mgkg^{-1}), while lead concentration on a dumpsite soil at different depths were; 0 - 15 cm (1.3 mgkg^{-1}), 15 - 30 cm soil depth (0.7 mgkg^{-1}) and on control or uncontaminated sites was 1.1 mgkg^{-1} which showed a significant ($P \leq 0.05$) differences between each of the sites (Olowookere *et al*., 2018).

2.4 Availability of Heavy metals in soils and uptake by plants on dumpsites

Soil is a precious natural resource upon which economic activity like agriculture and existence of life depend (Getachew and Habtamu, 2015) but its properties and quality can be adversely affected by the over concentration of waste released from agriculture, industry, municipal and individual household (Soffianian *et al*., 2014). These wastes deteriorate the quality of soil and influences sustainable development (Getachew and Habtamu, 2015). The situation by which accumulation of heavy metals are concentrated at the soil-surface than the sub-surface is reported by Amadi *et al*. (2012) and Ololade (2014) in that, soils show remarkably high levels of metals such as copper, and lead which decrease with depth, and is the reason why surface soils have been found as better indicators for metabolic burdens (Anikwe and Nwobodo, 2002). An understanding of the occurrence and availability of heavy metals and metabolic burdens in soils are of major importance to environmental health, crop and livestock production, food and water quality and ecotoxicology.

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Heavy metal dynamics in soils are complex, and the bioavailability, mobility, and toxicity of metals in the soil fractions are influenced by variety of factors including the properties of both the soil and the metal (Adriano *et al*., 2004; Buekers, 2007; Naidu and Bolan, 2008). Therefore, an understanding of the effects of soil properties on the behaviour of heavy metals in the soil is essential for assessing the extent of the soil contamination with metals (Alamgir, 2017) from dumpsites. Heavy metals, once entered the soil can undergo a number of processes that may be retained in soil solution as free ions or complexed to inorganic or organic ligands; adsorbed onto soil surfaces; hydroxides and carbonates; or fixed chemically as solid compounds (Lasat, 2000). The metals may also subject to plant uptake, transport through the vadose zone, and diffuse into porous materials (Alamgir, 2017).

The concentration or availability of metals in soil is controlled by various physical and chemical processes such as exchange, adsorption and desorption, complexation, precipitation and dissolution, oxidation, reduction, sequestration and occlusion, diffusion and migration, metal competition, biological immobilization and mobilization and plant uptake (Kabata – Pendias, 2010; Wuana and Okieimen, 2011).

Alamgir (2017) discussed that, metal behaviour in soils is a dynamic process and bioavailability of metal is regulated by physical, chemical and Biological properties of soils. Many other elements such as lead (Pb) and Copper (Cu) can also be found in vegetables and accumulate in the food chain (Pan *et al*., 2016). Plants like vegetables can take up these metals by absorbing from polluted soils and by atmospheric deposition of particulate matter from different sources and are first absorbed in the apoplast of roots and transported further into other parts of the plant cells (Gupta

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et al., 2019). Plants roots uptake of metals is controlled by many factors such as soluble contents of trace elements (metals) in soil, soil pH, organic matter, cation exchange capacity, plant growth stages, crop type, fertilizers and soil type etc. (Lente *et al*., 2014; Yadav *et al*., 2018).

A soils redox potential which determines the tendency of the soil solution to accept or donate electrons (Sheoran *et al*., 2016) is very important because, Gupta *et al*. (2019) found that, metals are present in their ionic forms in the soil solution. Thus, the mobility of such metals from soil to plants depend on their oxidation state for example, cu exists in two oxidation states of which the reduced form cu is quite insoluble in water while cu is highly soluble and readily available in the soil solution to the plants (NRC, 2003).

Transportation plays a significant role in metals or trace elements accumulation in plants in that, trace elements are transported to the ground part of the plant and then accumulated under the effect of transpiration (Gupta *et al*., 2019). Also, when transpiration is flourishing, plant accumulates more trace elements and its enrichment capacity is also stronger (Hao *et al*., 2012). Gupta *et al*. (2019) found that, leafy vegetables accumulate much higher content of trace elements than other vegetables and crops due to higher translocation and transpiration rate. The transfer of metals from root to stem and then to fruit during the transpiration and translocation process is longer in non-leafy vegetables and results in lower accumulation (Itanna, 2002; Khan *et al*., 2009).

Plants absorb both essential non - essential elements from the soil in response to concentration gradient and selective uptake of ions or by diffusion (Peralta - Videa *et al*., 2009). Also metal distribution in plants is quite heterogeneous and is controlled by genetic environmental and toxic factors (Natasa *et al*., 2015). The dynamics of heavy metals in plant - soil interactions depend mainly on the level of soil contamination and plant species (Guala *et al*., 2001). Different plant parts contain different heavy metals (Natasa *et al*., 2015) because plants absorb heavy metals from the soil through the root and from the atmosphere through above ground vegetative organs (Mmolawa *et al*., 2011). Ukpong *et al*. (2013) shares a view that, in order for root uptake of heavy metals to occur, a soluble species must exist adjacent to the root membrane for some finite period and also concluded that, the waste dumpsites worked on had higher concentration of heavy metal than control site and that of the surface soil (0 - 15 cm) than subsurface soil (15 - 30 cm) depth, by extension this means that, deep rooted crop might have lower metal than shallow rooted crop. Amusan and Olawale (2005) found that, the rate of metal uptake by plants could be influenced by factors as metal species, plant species, soil pH, CEC, organic matter, soil texture and interaction among the target elements.

2.4.1 The role of soil properties on metal availability in soils

The soil is one of the most important natural resource which provides the main mineral elements for plants growth and crop production (Uma *et al*., 2016). The formation of 1cm top soil layer requires 100 – 400 years (Deshmukh, 2012). The physicochemical properties of metal ions that influence metal sorption rate, include atomic weight, ionic radius, hydrated ion radius, electronegativity, reduction potential and covalent bonding couple with metals behaviour in soils as a dynamic process and how its bioavailability is regulated by physical, chemical and biological properties of the soil (Alamgir, 2017). Kirmanni *et al*. (2011) noted that, large number of factors control metal accumulation and bioavailability associated with soil and climatic conditions, plant genotype and agronomic management. Some recent studies have indicated that, there is a significant impact of carbonates on the sorption and retention of metals (Shirvani *et al*., 2006; Ahmed *et al*., 2008; Irha *et al*., 2009).

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All the physicochemical and biological properties are useful but the factors considered most important are: soil pH, soil texture, clay mineralogy, organic matter, redox potential, and cation exchange capacity (CEC) (Adriano, 2001; Bolan *et al*., 2013; Selim, 2013). Several studies have indicated the possibility of the combined effects of soil properties on metals sorption and desorption (Harter and Naidu, 2001; Appel and Ma, 2002; Dutta *et al*., 2011).

2.4.1.1 Soil pH

The soil pH is defined us the negative logarithm of the hydrogen concentration (Alamgir, 2017) generally has the greatest effect of any single factor on the solubility or retention of metals in soils (Ghosh and Singh, 2005; Alloway, 2012). Soil pH or hydrogen ion concentration is an important quality of natural soils (Umar *et al*., 2016) and pH of natural soil has between 7 - 8.5 but a variation may be due to biological activity, temperature, disposal of municipal waste (Oyedele *et al*., 2008). Umar *et al*. (2016) further explained that, soil pH directly affects the life and growth of plant soil.

Soil pH is a master variable influencing the chemical, physical and biological properties of soil (Chakraborty, 2015; Neina, 2019) as in the case of a metal like cupper whose uptake by plants is enhanced by low soil pH (Rajkumar *et al*., 2012). A study has established that, with increasing soil pH, the solubility of most trace elements will decrease leading to low concentration in soil solution (Kabata – Pendias, 2011). At acidic pH medium, more protons (H^+) are available to saturate metal binding sites; therefore, metals are less likely to form insoluble precipitates

(Alamgir, 2017). Generally metal sorption increases with increasing pH and when pH falls below 5, metals mobility is enhanced as a result of the increased proton concentration (Mclaughlin *et al*., 2000; Paulose *et al*., 2007). Metal availability is relatively low when pH is around 6.5-7, (Adelekan and Alawode, 2011), but lower pH would favour availability, mobility and redistribution of metals example Pb and Cu in the various fractions (Oviasogie and Ndio Kwere, 2008). Proshad *et al.* (2018) share a similar view that, at low soil pH ($pH<5$), solubility of hazardous elements are increased. Eze *et al.* (2018) have further reported that, heavy metals are generally more mobile at $pH < 7$ than $pH > 7$.

At basic conditions, metal ions can replace such protons to form other species, such as hydroxo – metal complexes (Olaniran *et al*., 2013). Desorbing protons can leave negatively charged groups at the surface, which act as Lewis bases that coordinate metal ions (Alamgir, 2017) and the adsorbed protons can form proton bonds between surface groups and metal complexes and generate positive charges at the surface repelling or attracting respectively positively or negatively charged metal complexes (Selim and Kingery, 2003).

Alamgir (2017) concluded that, soil pH increases are often correlated with mineralogy, changes in solution chemistry and base cation concentration at high pH; at lower pH there is high acidic cation concentration and higher metal solubility. Gupta *et al*. (2019) have found that pH is considered to be the main factor which affects the solubility of metals in the soil and this assertion was earlier confirmed by Sheoran *et al*. (2016) that, metal decreases at high pH and increases at low pH values. A decrease in soil pH increases the mobility of positively charged heavy metals as a result of proton competition with these metals and decrease in negative binding sites (Horckmans *et al*., 2007) and under alkaline (increase pH) conditions, functional groups present in soil organic matter, dissociate, thereby increasing the bioavailability of heavy metals that are bound to organic matter (Fine *et al*., 2005).

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2.4.1.2 Soil Texture and Clay Mineralogy

Soil texture and mineral types play an important role in mobility of metals in soil and it reflects the relative amounts of sand, silt and clay particles in a soil (Alamgir, 2017). The texture of soil influences the solubility and bioavailability of metals in the soil and this is due to the fact that, the availability of trace elements is highest in loamy sand followed by clay loam, and find textured clay soils (Gupta *et al*., 2019). Sheoran *et al*. (2010) further discussed that, trace elements retainability is higher in fine-textured soils (clay and clay loam) as compared with coarse – textured soils (sand) due to the presence of more pore spaces in sand. Clay fraction of a soil contain particles less than 0.002 mm in size, particles less than 0.001mm are the soil colloids and the most active portion of the soil which largely determines the physical and chemical properties of a soil, clay has a high sorption capacity and a strong ability to bind metallic elements due to their large specific area, clay has chemical and mechanical stability, clay is layered structured and have high cation exchange capacity (CEC) (Alamgir, 2017). The larger pore space and lower sorption capacity cause sandy soils to weakly absorb heavy metals unlike clay soils with high sorption capacities that play an importance role in metals absorption by plants (Alamgir, 2017).

2.4.1.3 Soil Organic Matter

Organic carbon in soils consists basically of humic substances which are formed by decomposition of organic matter and the humic substances from organic source have a powerful complexing and chelating entities whose sorption characteristics or properties depend on their chemical composition (Nurudeen and Aderibigbe, 2013). Soil organic matter comprises of nonhumic substances and humic substances, the humic substances or humus is comprised of humic and fulvic acids (Gupta *et al*., 2019).

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The main mechanisms involved in the retention of metals by organic matter are complexation and adsorption but their sphere and ion exchange reaction may also take place sometimes (Evans, 1989). McBride *et al.* (2015) reported no correlation between organic matter and specific metals like lead (Pb). Soil organic matter has been of particular interest in studies of heavy metal sorption by soils, because organic matter is known to form strong complexes with heavy metals which has a high affinity for humic acids, organo-clays, and oxides coated with organic matter (Connell and Miller 1984: Elliot *et al*., 1986; Faffney *et al*., 1996; Karaca, 2004; Ghosh and Singh, 2005).

Soil organic matter serves as a reactive adsorbent pool for trace metals, due to their high surface area and their high reactivity associated with various S-O- and N-functional group. Organic matter can reduce or increase the bioavailability of heavy metals in soil through immobilization or mobilization by forming various insoluble or soluble heavy metal organic complexes (Alamgir, 2017). The complexation reaction follows the formula;

$$R - L_{1+} + M_{m+} \rightarrow R - L - M_{m+1-} \qquad (2.1)$$

Where R is the C - chain, L the active group which actually binds, M the metal, and m +1 are the valencies of metal and ligand, respectively. The effect of soil organic matter on metals in soils depends on its amounts, composition, and dynamics (Alamgir, 2017). Soil organic matter is important for the retention of metals in the soil thereby decreasing mobility, bioavailability and enhances the usefulness of soil for agricultural purposes (Akpoveta *et al*., 2010).

Several studies have indicated that the reactions between organic acid and heavy metals are related to the amount and place of the carboxyl and hydroxyl groups (Shan *et al*., 2002; Gao *et al*., 2003: Schwab *et al*., 2008). Generally citric acid is the most effective in terms of desorption of different

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metals (Cu, Pb), followed by malic > acetic > tartaric > oxalic acid as organic acid with more carboxyl group form more stable ligand (Vranova *et al*., 2013; Yan *et al*., 2014), the more stable of the ligand formed the more difficulty for it to be adsorbed by the soil and sediment, and thus metal leaching is much easier (Gao *et al*., 2003).

The binding of heavy metals by organic matter is a complex process, due to the diversity of its connections with the mineral phase (Harter and Naidu; 2001; Lamb, 2010). Organic matter which is described as the level of mineral elements for plant development and growth (Odai *et al*., 2008) has been classified for cultivation as; < 2.0% as low; (values below critical limits); 2.1 – 3.0% as medium (values above critical limit) and >3.1 as high (Enzezer *et al*., 1988). Most organic matter contents on dumpsites soils are high and Odai *et al.* (2008), explained that, dumpsites receives much organic wastes and this confirms why farmers consciously choose to farm on such sites. Eze *et al.* (2018) reported that, high values of soil organic matter in dumpsite soils may be to due high anthropogenic activities such as indiscriminate dumping of refuse and decomposition of dead plants. Qadir *et al.* (2008) also affirmed that, dumpsites have higher organic matter contents.

2.4.1.4 Cation Exchange Capacity (CEC)

Cation exchange capacity (CEC) is a dominant factor in heavy metals retention and is defined simply as the sum total of exchangeable cations that a soil can adsorb or the number of cation adsorption sites per unit weight of soil expressed as centimoles per kg (cmolkg^{-1}) (Alamgir, 2017). CEC is a factor that plays a vital role in the availability of metals in soil (Gupta *et al*., 2019). The soil with low CEC such as sand has less binding power to metals and other cations as compared to the soil with high CEC such as clay (Bhargava *et al*., 2012). Soil CEC levels increase

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concomitantly with increasing soil clay content, while the availability of metal ions decreases (Gupta *et al*., 2019).

CEC for clay soils usually exceeds 30 cmolkg^{-1} while the value ranges from 0 – 5 for sandy soils (Alamgir, 2017). The capacity of soils for adsorbing heavy metals is correlated with their CEC (Fontes *et al*., 2000; Harter and Naidu, 2001). The greater the CEC values, the more exchange sites of soil minerals will be available for metal retention (Alamgir, 2017).

Table 2.1 Relationship between cation exchange capacity (CEC) and soil texture

CEC (meq100g^{-1})	Soil Texture
3 - 5	Sands
10 - 15	Loams
15 - 25	Silt Loams
20 - 50	Clay and Clay Loams
50 - 100	Organic soils

Source: Culman *et al.* (2019)

2.4.1.5 Oxidation - Reduction Potential

Oxidation – reduction potential (redox potential) is one of the critical factors regulating the speciation and bioavailability of metals in soils (Alamgir, 2017). The redox potential of soil determines the tendency of the soil solution to accept or donate the electrons (Sheoran *et al*., 2016). Alamgir (2017), further explained that oxidation and reduction (redox potential) reactions are common in soils which occur together because as an electron cannot exist as an isolated entity; it is transferred from one species (the reductant) to another (the oxidant).

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Several metals are present in their ionic forms in the soil solution thus the mobility of such metals from soil to plants depends on their oxidation state for example, Cu exists in two oxidation states of which the reduced form i.e cu is quite insoluble in water while the oxidized form (Cu) is highly soluble and readily available in the soil solution to the plants (NRC, 2003).

The extent to which a soil is reduced or oxidized is generally assessed by the values of ‘Eh and Pe’ where ‘Pe’ is a redox potential which is expressed in terms of electrochemical energy (millivolts) and assumes a system at thermodynamic equilibrium (Alamgir, 2017). Oxidized soils have values ranging from +400 to +700 mV while reduced soils may have values from -250 to 300 mV (Roberts *et al*., 2005).

Redox reactions play a major role in the formation and reactivity of some soil oxides (Cu and Pb) responsible for metal sorption and also controls the chemical speciation of several metalloid contaminants (Pb and Cu) thus affecting sorption (McLaughlin *et al*., 2000). Generally reducing conditions cause a reduction in heavy metal mobility (Kabata – Pendias and Pendias, 1991; Gonsior *et al*., 1997). Oxidation – reduction reactions may not only affect the partitioning of redox-active trace metals like Cu, or Pb, but also of redox stable metals like Cu, or Pb, in soil or aquatic environments (Lander and Reutherr, 2004).

2.4.1.6 Interaction with other metals

The presence of certain trace elements affects the availability of other metals in the soil and hence in the plant (Gupta *et al*., 2019). Antagonistic and synergistic behaviour thus exists among trace elements (Chibuike and Obiora, 2014), example, Cu is reported to antagonize the inhibitory effect of Pb on the total amount of mineralized carbon (Salgare and Acharekar, 1992). Similarly, Cu and Pb have been reported to compete for the same membrane carriers in plants (Clarkson and Luttge, 1989). Lead availability is affected by the other metals and reduced when interacting with Pb and

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Cu, due to antagonistic effect (Orronoa *et al*., 2012). Despite the fact that presence of one trace elements affects the presence of another one, different species of some metal also affect each other (Abedin *et al*., 2002).

2.4.2 Plant related factors

An uptake and accumulation ability of different trace elements (heavy metals) is dissimilar in different vegetables (Yadav *et al*., 2018) and crops in general, due to the difference in physiology, morphology and anatomy of each plant, leaf inclination angle and branch density (Shahid *et al*., 2016) are some morphological characters which affect the foliar uptake of trace elements. Like root uptake, foliar uptake of trace elements may occur in a dose dependent manner (Gupta *et al*., 2019). Xiong *et al*. (2014) suggested that small particles might diffuse through both the stomatal and cuticular pathways to enter the plant. Leaf penetration through stomatal pathway is generally easier because the cuticle of the sub-stomatal cells is comparatively thinner compared to external one (Roth – Nebel, 2007). The plant with numerous thin roots has high accumulation capacity of trace elements than one with few thick roots (Chandran *et al*., 2012).

Transpiration also plays a significance role in trace elements accumulation in plants (Gupta *et al*., 2019) because when transpiration is flourishing, plant accumulates more trace elements and its enrichment capability is also stronger (Hao *et al*., 2012). Leafy vegetables accumulate much higher translocation and transpiration rates (Gupta *et al*., 2019). The transfer of metals from root to stem and then to fruit during the transpiration and translocation process is longer in non-leafy vegetables and results in lower accumulation (Itanna, 2002; Khan *et al*., 2009): Plants absorb essential and non - essential elements from the soil in response to concentration gradient and selective uptake of ions or by diffusion (Peralta -Videa *et al*., 2009).

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2.4.3 Effects of heavy metals on Soil

Heavy metal pollution of the soil is caused by various metals especially Cu and Pb (Hinojosah *et al*., 2004) whose accumulation is an important requirement in environmental science (Nurudeen and Aderibigbe, 2013). Heavy metals sorption in soil is influenced by factors such as clay, pH, CEC and organic matter content (Adekunle *et al*., 2007). Metals pollution occur largely from industrial domestic and agricultural wastes as well as composition of fossil fuels by automobiles and (Nurudeen and Aderibigbe, 2013).

The adverse effects of heavy metals on soil biological and biochemical properties are well documented (Singh and Kalamdhad, 2011). Soil properties like organic matter, clay contents and pH having major influences on the extent of the effects of metals on biological and biochemical properties (Speira *et al*., 1999). The soil enzymes activities are influenced in different ways by different metals due to the different chemical affinities of the enzymes in the soil system (Karaca *et al*., 2010).

An increase in metal concentrations adversely affects soil microbial properties such as respiration rate and enzyme activities (Singh and Kalamdhad, 2013). The contamination of soil by heavy metals are of global concern and present a serious problem (Muniatu and Otiato, 2010; Panagos *et al*., 2011) because soils contamination had shown to inhibit soil microbial activities and in turn reducing soil fertility, inhibiting the germination of certain seeds and producing nutrient imbalance in plants with adverse effect on synthesis and functioning of many biologically active compounds (Nurudeen and Aderibigbe, 2013).

2.4.4 Effects of Heavy Metals on Plants

Plants have a natural propensity to take up metals (Achazai *et al*., 2011). Heavy metals effect on the growth of plants varies according to the particular heavy metal involved in the process (Chibuike and Obiora, 2014). The uptake of heavy metals by plants and subsequent accumulation along the food chain is a potential threat to animal and human health (Sprynskyy *et al*., 2007). These heavy metals are potentially toxic to plants and thus resulting in chlorosis, weak plant growth, yield depression and may even be accompanied by reduced nutrient uptake and reduced activity to fix molecular nitrogen in leguminous plants (Guala *et al*., 2010). Elevated lead (Pb) in soils may decrease soil productivity and a very low lead (Pb) concentration may inhibit some vital plant processes, such as photosynthesis, mitosis and water absorption with toxic symptoms of dark green leaves, wilting of older leaves, stunted foliage and brown shoot roots (Bhattachargya *et al*., 2008).

2.4.5 Effects of Heavy Metals on Human and Animal Health

Utilization of food crops contaminated with heavy metals is a major food chain route for human exposure (Singh and Kalamdhad, 2011). Heavy metals become toxic when they are not metabolized by the body and accumulate in the soft tissues (Sobha *et al*., 2007). Ingestion of toxic metals like cupper has undesirable impacts on humans and the associated harmful impacts become perceptible only after several years of exposure (Khan *et al*., 2008).

Pb toxicity on large organs like liver, placenta, kidneys, lungs, brains and bones have been identified (Sobha *et al*., 2007). Clinical signs of Cu toxicosis have been reported as vomiting, diarrhea, bloody urine, yellow mucus membrane, liver failure, kidney failure and anaemia (Duruibe *et al*., 2007).

Excessive human intake of Cu may lead to severe mucosal irritation and corrosion, widespread capillary damage, hepatic and renal damage and central nervous system irritation followed by depression (Singh and Kalamadhad, 2011). Excessive pb exposure may vary from skin irritation to damage to the lungs, nervous system, and mucos membranes (Argun *et al*., 2007). Acute Pb poisoning may result to a dysfunction in the kidney, reproductive system, liver and brain which may lead to sickness and death (Odum, 2000). Pb is toxic and has no known function in human biochemistry and physiology (Singh and Kalamdhad, 2011). As inhibits the production of adenosine triphosphate (ATP) during respiration (Singh and Kalamdhad, 2011).

Heavy metals are not only harmful to people who work (farm) on contaminated soils, but people who have been living in nearby areas (Abishek and Surrendra, 2016) and consumers of farm products from those areas. Although Cu is needed for biochemical process in crops, increased concentration of Cu is detrimental to human health (Tariq *et al*., 2016).

2.5 Crop Production on Dumpsites

Many dumpsites in the rural and urban communities in Ghana including abandoned refuse dumpsites are used for cultivation of crops especially vegetables (Twumasi *et al*., 2016). The constructions of roads and buildings have been blamed for the losses of otherwise agricultural lands (Kugelman, 2012). Most Ghanaian communities over the years have promoted backyard farming (Appeaning, 2010) because many families in these rural and urban communities depend upon backyard farming (Zezza and Tasciotti, 2010) which include both livestock and crops (Cofie *et al*., 2005). The activities of backyard dumpsite farmers are not without soil pollution problems which are full of serious health implications especially with regards to crops grown on such soils

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(Steffang *et al*., 2017; Nwaogu *et al*., 2014). However, these dumpsites are commonly used for direct cultivation of vegetables and also as a good source of compost to support mainland agricultural activities (Owusu – Sekyere *et al*., 2013; Mwingyine, 2008). Both active and closed dumpsites in Ghana are all utilized since these soils are considered as nutrient rich by farmers in Ghana using wide range of crops from vegetables to tree crops for food, medicinal and other economic use.

2.5.1 Plantain (*Musa sapientum*) farms on dumpsites

Plantain is a tree – crop herb belonging to the Musaceae family with high starchy fruits which serve as a staple crop in most parts of the tropics including Nigeria (Iniobong and Uduakobong, 2017) and Ghana. Plantain is one of the common food tree crops found on dumpsites in Ghana, the reason being that they thrive well in waste dumpsites soils (Iniobong and Uduakobong, 2017). Plantain fruits have high fibre content which makes it a diet for lowering blood cholesterol and relieving of constipation thereby putting colon cancer at bay (Okareh, 2015). In Ghana, apart from human feeding on the mature fruits, the fresh leaves are also used to feed livestock. Plantain has a high demand for organic matter and thrives well in waste dumpsites where they produce healthy bunches of fruits (Iniobong and Uduakobong, 2017). Leachates from these dumpsites contribute to heavy metals in the soil (Ukpong *et al*., 2013) and it is the commonest occurring group of soil contaminant (Ideria *et al*., 2010). In Ghana, due to scarcity of arable lands in urban areas plantain is cultivated in dumpsites in densely populated cities and rural communities, most especially in strategic locations where all sorts of solid waste materials are dumped (Iniobong and Uduakobong, 2017).

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Higher levels of heavy metals such as lead, cupper were found to be higher in waste dumpsites soils than in soils, some distances away from the dumpsites (Ukpong *et al*., 2013; Amos – Tautau *et al*., 2014; Olufunmilayo *et al*., 2014; Tanee and Eshami – Mario, 2015) and growing plantain in such dumpsites absorbed these heavy metals along with other nutrients and accumulated them in their fruits. It was found out that all the dumpsites fruits had significantly (p = 0.05) higher heavy metals contents than those from the control site for example: dumpsite fruits Pb levels (7.63 – 8.67 mgkg^{-1}), control site fruits Pb (1.13 mgkg^{-1}); dumpsite site pb levels (6.59 – 7.33 mgkg^{-1}), control site pb levels (2.23 mgkg^{-1}); dumpsites fruits pb levels (2.66 – 3.36 mgkg^{-1}), control site fruits (1.14 mgkg^{-1}); dumpsites fruits Cu levels (2.44 – 5.26 mgkg^{-1}), control fruits Cu levels (2.00 – 3.22 mgkg-1) (Iniobong and Uduakobong, 2017). Plantain has shown the ability to absorb metals and metals concentrations in their leaves have also showed a good correlation with the concentration of metals in soil (Bekteshi and Bora, 2013).

2.5.3 Lettuce (*Lactiva sativa*) Farms on Dumpsites

Dumpsites agricultural lands contribute to vegetables production especially in urban communities where arable lands are scarce (Dubbeling and De Zeeuw, 2011) and most of these vegetables used for cultivation are hyper accumulators of most of the essential heavy metals (Singh *et al.*, 2012) such as lead and cupper (Twumasi *et al*., 2016). The dumpsites used for agriculture are important sources of dangerous heavy metals derived from components of industrial products (Fuge, 2013; Wuana and Okieimen, 2011) and thus agricultural activities on such lands provide entry route for heavy metals in the food chain (Twumasi *et al*., 2016). Most leafy vegetables are hyper accumulators of most of the non - essential heavy metals (Singh *et al*., 2012).

Higher concentrations of heavy metals have earlier been detected in fruits and vegetables harvested from waste dumpsites (Imasueb Omorogiera, 2013; Cortez and Ching, 2014; Tanee and Eshalomi - Mario, 2015). When plants are cultivated on these dumpsites soils, they absorb some of these heavy metals and bioaccumulate them in their roots, stems, fruits, grains and leaves (Fatoki, 2000). A study on a dumpsite and a control site found that, metal concentrations in lettuce on dumpsites Cu level (0.13 - 0.67 mgkg^{-1}) was higher than control site lettuce Cu level (0.010 mgkg^{-1} Cu) while control soil Cu level (0.243 - 13.623 mgkg^{-1}) was lower than Cu level ranged in dumpsite soil (90.013 - 7.197 mgkg^{-1}) (Twumasi *et al*., 2016). A report indicates that maximum allowable level of Cu in soil is supposed to be 0.27 mgkg^{-1} in lettuce 0.02 mgkg^{-1}, Cu level in fruity vegetable was 0.05 mgkg^{-1}; Cu while Pb maximum allowable level in soil is

0.420 mgkg^{-1}, in lettuce 0.3 mgkg^{-1} Pb and in fruity vegetable it is expected to be 0.1 mgkg^{-1} Pb (FAO / WHO, 2011).

Table 2.2 Metal concentration levels in cultivated lettuce (*Lactuca sativa L.)*

Heavy metals	Mean concentration of metal (mgkg^{-1})
Cu^{2+}	8.00
Pb^{2+}	5.942

Source: Kabir *et al*. (2011)

Table 2.3 Allowable concentration limit of heavy metals in soils and plant fruits (mgkg^{-1})

Metals	Concentration in Soil (mgkg^{-1})	Concentration in Plants / fruits (mgkg^{-1})
Pb	100.00	0.30
Cu	10.00	73.00

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Source: WHO / FAO (Chiroma *et al*., 2014): in Iniobong and Uduakobong (2017)

Table 2.4 FAO/WHO guidelines for metals in food and vegetables

Metals (mgkg^{-1})	levels in plants (mgkg^{-1})	Normal range in plant (mgkg^{-1})
Cu	30	2.5
Pb	2	0.50 – 30

Source: FAO/WHO (2011)

Table 2.5 Concentration ranges of metals (mgkg^{-1}) in soils and plants and critical concentrations in plants

Metals	Normal range in soils (mgkg^{-1})	Normal range in plants (mgkg^{-1})	Critical plant concentration (mgkg^{-1})
Cu*	2 - 250	5 - 20	20 – 100
Pb*	2 - 300	0.2 - 20	30 – 300

Source: * Radojevic and Baskin (2006); #Stewart *et al.* (1974)

Table 2.6 WHO/FAO heavy metals threshold in soils

Metals	Soil metal limit (mgkg^{-1})
Cu	100.00
Pb	5.00

WHO/FAO (2001); FAO/WHO (2007) *

Table 2.7 Heavy metal permissible (mgkg^{-1}) limits in plants

Metal	Level	Level

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Cu	10**	100***
Pb	2**	100***

***FAO/WHO (2007); **FAO/WHO (2009); *(Shal *et al*., 2011)

Table 2.8 Permissible limit for total metals (mgkg^{-1}) in various soil pH ranges in UK and Germany

	UK (1989)			Germany (1992)	
Metal	pH 6 – 7	pH 5.5 - 6	pH 5 – 5.5	pH 6 - 7	pH 5 - 6
Cu	135	100	80	60	60
Pb	300	300	100	100	100

Permissible limits Adapted from (Ghorbani *et al*., 2006)

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CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

Dumpsites and background soils were collected from six different locations in the Ashanti region of Ghana were used for the study. The Ashanti region lies between latitude 5^{o} 50ʿ 7.46’’ N and longitude 0^{o} 15ʿ 2.25’’ W. Soils in Ashanti region are mainly of two types, Forest ochrosols are found in the southern districts whilst the savanna ochrosols are confined to the northern districts. The pH and nutrient status of the soils support crop production (Soil Research Institute, CSIR, 2020). The physical characteristics showed that the soil Bulk density and texture classification can support food and cash crops (MOFA, 2020). The Ashanti region experiences double maxima rainfall in a year, with peaks in May/June and October. Mean annual rainfall is between 1100 mm and 1800 mm. The mean annual temperature ranges between 25.5^{0} C in the southern districts and 32^{0} C in the northern parts of the region. Humidity is high averaging about 85% in the southern districts and 65% in the northern part of the region (MOFA, 2020).

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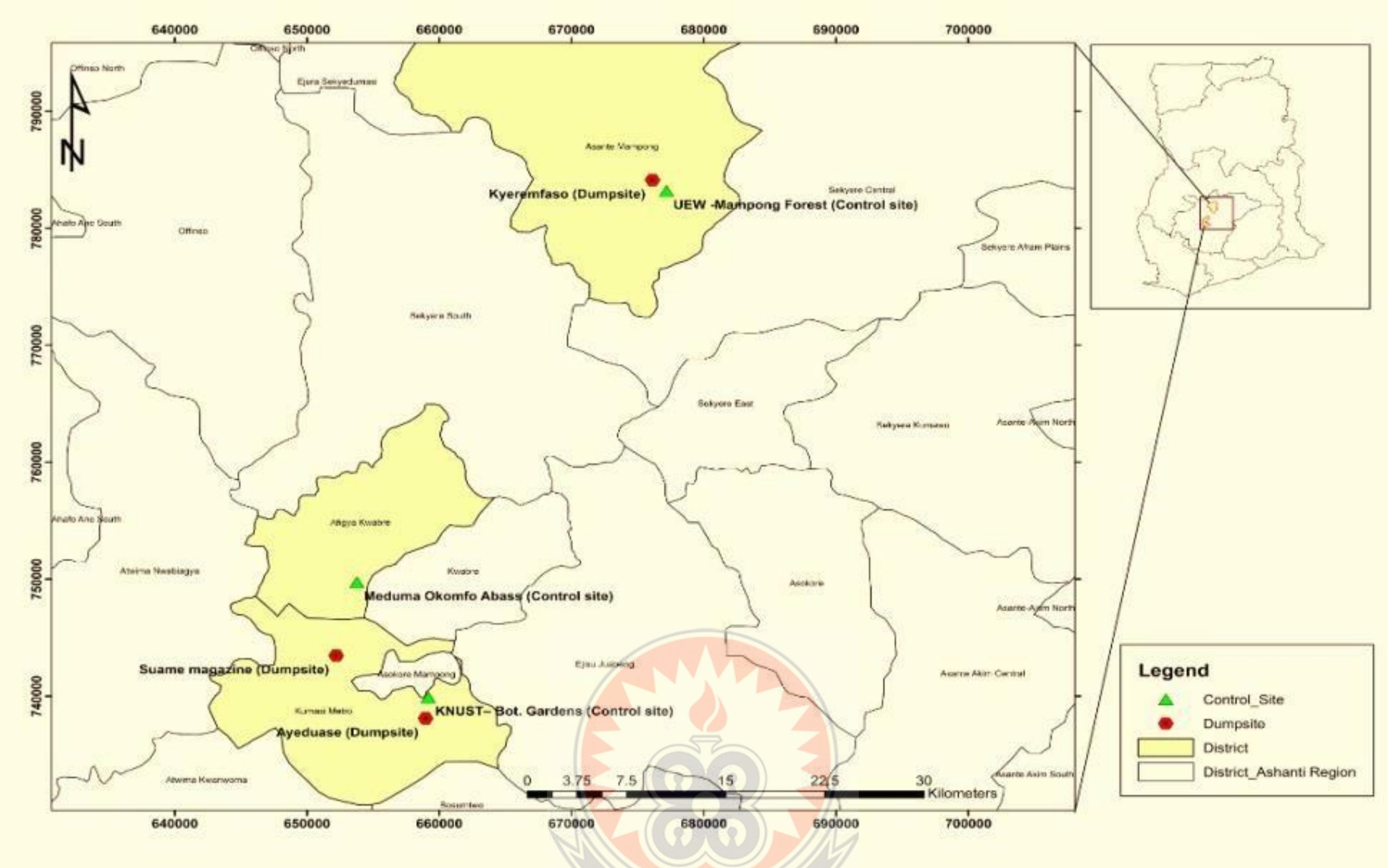

Figure 3.1: The Map of Ashanti region of Ghana showing the six studied locations

3.2 Soil samples preparation

Soil samples were picked at 0 - 30 cm of soil depth and fill them into 1 m^2 pots and arranged the pots in a RCBD with three replications on the field giving a total of eighteen experimental pots in Ashanti region from February to March, 2019. Soil samples were picked passed through 2 mm sieve and placed in a zip - lock bags for background soil physicochemical analytical studies at the chemistry department of soil Research Institute, Kwadaso Kumasi for a background studies and at KNUST, Department of Chemistry analytical laboratory for heavy metals determination.

3.3 Lettuce Cultivation

Lettuce seedlings were transplanted into pots on the field after twenty one days at the nursery. All best farming practices like weeds control were observed. Lettuce plants were harvested at 7 weeks after transplanting.

3.3.1 Lettuce Samples Preparation

Lettuce shoots and roots cultivated on dumpsite and background soils in pots under field conditions were sampled and washed with deionized water and oven dried at 60 ºC for 24 hours and ashed in furnace at 450 ºC before bagging in a zip - lock bag for analysis.

3.3.2 Analysis of Some Chemical Properties of Soil Samples

Prior to the assessment of the metals, routine soil characteristic was carried out at CSIR chemistry laboratory, Kwadaso - Kumasi, Ghana. Soil particle size analysis was determined (Day, 1965). Bulk density was determined using the core method (Blake, 1965)g , soil pH (H_2O) was measured (Rowel, 1994) , total organic matter was determined using the wet oxidation method by Walkley - Black, (Page *et al.*, 1982), total nitrogen was determined by the Micro Kjeldahl (Anderson and Ingram, 1989). Available P was determined by Bray 1 method, and the total exchangeable calcium and magnesium were determined by EDTA titration method, while potassium and sodium were assessed using a flame photometer (IITA, 1985). CEC was determined using (FAO, 2008).

3.4 Total Metal Concentration Analysis

3.4.1 XRF Analyses

The studied soils and plants metals analyses were determined at the Kwadaso Soil Research laboratory. Heavy metals in soils and plants samples were examined using a Niton XL3t GOLD field portable X-ray fluorescence (FP-XRF) spectrometer following the United States Environmental Protection Agency Method 6200 protocols (US - EPA, 2007; Darko *et al.*, 2020). The FP-XRF gives results of 24 elements but 9 (Cu and Pb) toxicologically important ones were used in this study. Optimization of the XRF to generate useable data was also conducted in the study (Davidson, 2013).

3.5 Data Analysis

Data obtained from this work were analyzed using Minitab ® 16. Statistical analyses such as ANOVA by using LSD separate means at 5 % probability level. Correlation and regression analysis were performed using SPSS (version 20).

3.5.1 Evaluation of contamination techniques

3.5.1.1 Geoaccumulation index (Igeo)

This model was employed to quantify the degree of pollution in the refuse dump soils. The geoaccumulation index was calculated according to equation 1.

$$I_{geo} = \text{In}\,(C_n / 1.5B_n) \qquad (1)$$

Where C_n – measured concentration of metal in the refuse dump soil (mgkg^{-1});

B_n – background value of heavy metal (mgkg^{-1}); and 1.5 - background matrix correction factor (Förstener *et al.,* 1993; Sutherland, 2000; Agyarko *et al*., 2010).

3.5.1.2 Enrichment factor (EF)

The enrichment factor (EF) was calculated as;

$$EF = \frac{C_n\,(\text{sample}) / C_{ref}\,(\text{sample})}{B_n\,(\text{background}) / B_{ref}\,(\text{background})} \qquad (2)$$

Where C_n - is the content of the examined element in the examined environment (dumpsite soil)

C_{ref} - is the content of the examined element in the reference environment (background soil)

B_n - is the content of the reference element in the examined environment (dumpsite soil)

B_{ref} - is the content of the reference element in the reference environment (background soil)

(Buat - Menard and Chesselet, 1979; Agyarko *et al.*, 2014)

3.5.1.3 Transfer ratio (TR)

All the metals in the different samples were quantified using the transfer ratio (TR) in equation 4.

$$\text{Transfer Ratio} = C_{\text{plant}} / C_{\text{soil}} \qquad (3)$$

Where; C_{plant} - is the concentration of a specific metal in the plant (mgkg^{-1});

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C_{soil} - is the concentration of that metal in the soil (Hasan *et al.*, 2003)

3.5.1.4 Translocation factor (TF)

The translocation of metals from one part of a vegetable (crop) to another part of the plant is a function of root shoot transport, which can be expressed as the translocation factor (TF) (Gosh and Singh, 2005). It is expressed as:

$$TF = (C_{shoot} / C_{root}) \qquad (4)$$

Where, C_{shoot} is the concentration of the metal in the above ground portion of the vegetable (crop); C_{root} is the metal concentration in the below ground portion (Gosh and Singh, 2005). A plant will have a high capacity to transport element from root to shoot when the above ground concentration is higher than the below ground concentration (Nafiu, 2010).

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CHAPTER FOUR

4.0 RESULTS

4.1 Soil Physicochemical Properties

Soil physicochemical analytical studies conducted showed that Kyeremfaso Mampong dumpsite soil (KYE) and UEW Mampong background soil (UEW) have a sand texture. Suame Kumasi dumpsite soil (SUA) had a sand texture while Meduma Kumasi background soil (MED) was sandy clay Loam in texture. Both Ayeduase Kumasi dumpsite soil (AYE) and KNUST Kumasi botanical gardens background soil (KNUST) showed loamy sand texture. There was no significant difference between soil bulk densities of KYE (1.54 gcm^{-3}) and UEW (1.58 gcm^{-3}), SUA (1.12 gcm^{-3}) and MED (1.61 gcm^{-3}) and also between AYE (1.59 gcm^{-3}), KNUST (1.41 gcm^{-3}) (Table 1)

Soil pH showed a highly significant ($p = 0.01$) difference between KYE (9.04) and UEW (6.10) and also between SUA (6.67) and MED (7.95). There was a significant difference between AYE (8.40) and KNUST (6.07) ($p = 0.01$). Total organic carbon (TOC) was higher on KYE (1.91%) than on (1.73%), Higher TOC was recorded in SUA (10.83%) than on MED (2.08%) ($p = 0.01$). TOC showed no significant difference between AYE (1.56%) and KNUST (1.65%). Total organic matter (TOM) showed a similar trend with only SUA (18.69%) and MED (3.59%) which showed a highly significant ($p = 0.01$) difference between them. Total nitrogen showed a highly significant ($p = 0.01$) difference between SUA (0.21%) and MED (0.17%). Total N was significantly higher in AYE (0.30%) than in KNUST (0.15%). (Table 1).

Soil available P was significantly higher in KYE (790.43 $mgkg^{-1}$) than in UEW (17.77 $mgkg^{-1}$), SUA (73.58 P $mgkg^{-1}$) was significantly lower than in MED (118.45 P $mgkg^{-1}$), and similarly AYE (3.08 $mgkg^{-1}$) reported a significantly lower soil available P than in KNUST (218.68 $mgkg^{-1}$). (Table1).

The concentration of Ca was significantly higher in KYE (12.99 $meq100g^{-1}$) than in UEW (5.33 $meq100g^{-1}$) and also significantly higher in SUA (59.64 $meq100g^{-1}$) than in MED (13.63 $meq100g^{-}$

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^{1}), however, Ca was and lower in AYE (2.56 meq100g^{-1}) than in KNUST Kumasi (35.15 meq100g^{-1}). A similar trend was observed for Mg, K and Na (Table 1).

Exchangeable acidity was lower in KYE (0.02 meq100g^{-1}) than in UEW (0.25 meq100g^{-1}); SUA (0.10 meq100g^{-1}) and MED Kumasi background soil (0.05 meq100g^{-1}) showed no significant differences between them but AYE (0.02 meq100g^{-1}) and KNUST (1.20 meq100g^{-1}) showed a significant ($p = 0.03$) difference between them. CEC was higher on SUA (39.34 meq100g^{-1}) than in MED (18.18 meq100g^{-1}) with a highly significant ($p = 0.01$) difference between them. There was no significant difference for the CEC between KYE (8.58 meq100g^{-1}) and UEW (8.96 meq100g^{-1}); and also between AYE (7.38 meq100g^{-1}) and KNUST (7.68 meq100g^{-1}). ECEC generally showed a highly significant ($p = 0.01$) differences between each of the dumpsites and their background soils sampled. Base Saturation was generally high in all the dumpsites soil than in background soils and the only significant ($p = 0.03$) difference was between KYE (99.90 %) and UEW (96.73 %) (Table 1).

Table 4.1. Soil physicochemical properties of the soils from selected study sites in Ashanti region, Ghana

								Exchangeable cations							
Location	Texture	B.D	pH	T.O.C	T.O.M	Total N	Available P	Ca	Mg	K	Na	Exchangeable acidity	CEC	ECEC	Base saturation
		(gcm^{-3})		(%)		(mgkg^{-1})		(meq100g^{-1})							(%)
KYE	Sand	1.54	9.04	1.91	3.29	0.16	790.43	12.99	3.83	0.85	2.57	0.02	8.58	20.26	99.90
UEW	Sand	1.58	6.10	1.73	2.98	0.17	17.77	5.33	1.49	0.32	0.26	0.25	8.96	7.65	96.73
SUA	Sand	1.12	6.67	10.83	18.69	0.21	73.58	59.64	44.73	405	3.22	0.10	39.34	111.75	99.91
MED	Sand Clay Loam	1.61	7.95	2.08	3.59	0.17	118.45	13.63	1.49	0.45	1.01	0.05	18.18	16.63	99.10
AYE	Loamy Sand	1.59	8.40	1.56	2.69	0.30	3.08	2.56	0.85	0.35	0.46	0.02	7.38	4.23	97.49
KNUST	Loamy Sand	1.41	6.07	1.65	2.84	0.15	218.68	35.15	4.69	3.97	2.74	1.20	7.68	47.74	97.49
P - value		0.88	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.03	0.01	0.01	0.03
LSD (0.05)		0.99	1.51	1.88	0.99	0.02	21.70	1.37	1.35	1.51	1.79	0.75	1.29	1.59	1.51
CV (%)		0.45	11.30	31.40	9.60	5.80	12.28	3.50	7.80	0.64	0.75	0.79	4.70	2.50	0.80

Location: KYE - Kyeremfaso Mampong dumpsite soil; UEW – Mampong background soil; SUA - Suame Kumasi dumpsite soil; MED - Meduma Kumasi background soil; AYE - Ayeduase Kumasi dumpsite soil; KNUST - KNUST Kumasi botanical gardens background soil.

4.2 Total Metals Level in Soils from selected study sites in pots under field Conditions

Cu recorded a higher value in KYE (36.21 mgkg^{-1}) than in UEW (27.91 mgkg^{-1}). Cu in SUA (78.64 mgkg^{-1}) Kumasi dumpsite soil was higher than Cu in MED (23.63 mgkg^{-1}). Lower Cu level was recorded in AYE (33.70 mgkg^{-1}) than Cu in KNUST (36.55 mgkg^{-1}) (Table 2).

Pb level in KYE (43.77 mgkg^{-1}) was higher than Pb in UEW (11.41 mgkg^{-1}). Pb in SUA (36.24 mgkg^{-1}) was higher than Pb in MED (9.11 mgkg^{-1}). Pb level in AYE (75.32 mgkg^{-1}) recorded a higher value than in KNUST (10.46 mgkg^{-1}). Heavy metals level in dumpsite soils were generally higher than in background soils and were highly significantly ($p = 0.01$) different in concentration from each other (Table 4.2).

Table 4.2. Initial total Cu and Pb levels in soils in pots under field conditions

Total soil metals level (mgkg^{-1})

Treatment	Cu	Pb
KYE	36.21	43.77
UEW	27.91	11.41
SUA	78.64	36.24
MED	23.63	9.11
AYE	42.43	75.32
KNUST	34.24	10.46
P – value	0.01	0.01
LSD (0.05)	1.11	0.99
CV (%)	1.00	1.80

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Cu was of a higher value in KYE (27.12 mgkg^{-1}) than in UEW (22.19 mgkg^{-1}). Cu in SUA (124.23 mgkg^{-1}) was higher than Cu in MED (35.74 mgkg^{-1}). Higher Cu level was similarly recorded in AYE (29.24 mgkg^{-1}) than Cu in KNUST (23.12 mgkg^{-1}) (Table 4.3).

Pb level in KYE (16.19 mgkg^{-1}) was higher than Pb in UEW (9.36 mgkg^{-1}). Pb in SUA (24.33 mgkg^{-1}) was higher than Pb in MED (7.71 mgkg^{-1}). Pb level in AYE (59.54 mgkg^{-1}) recorded a higher value than in KNUST (9.04 mgkg^{-1}). Cu and Pb levels in dumpsite soils generally recorded higher levels than in background soils (Table 4.3).

Table 4.3. Total heavy metals level in soils in pots under field conditions at harvest

	Total soil metals level (mgkg^{-1})	
Treatment	Cu	Pb
KYE	27.12	16.19
UEW	22.19	9.36
SUA	124.23	24.33
MED	35.74	7.71
AYE	29.24	59.54
KNUST	23.12	9.04
P - value	0.01	0.01
LSD (0.05)	0.74	0.01
CV (%)	0.90	0.001

Treatments: KYE - Kyeremfaso Mampong dumpsite soil; UEW - Mampong Forest background soil; SUA - Suame Magazine Kumasi dumpsite soil; MED - Meduma Kumasi background soil; AYE - Ayeduase Kumasi dumpsite soil; KNUST - KNUST Kumasi botanical gardens background soil

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4.3 Heavy Metals level in Lettuce in Pots under field conditions

Heavy metals (Cu and Pb) level in lettuce shoots and roots in pots under field conditions showed that, in KYE, Pb levels in lettuce shoot (34.20 $mgkg^{-1}$) and root (23.56 $mgkg^{-1}$) were higher than Pb in lettuce shoot (14.64 $mgkg^{-1}$) and root (8.06 $mgkg^{1}$) in UEW. In SUA, Pb in lettuce shoot (21.01 $mgkg^{-1}$) and root (19.24 $mgkg^{-1}$) were higher than MED Pb in lettuce shoot (15.25 $mgkg^{-1}$) and root (7.91 $mgkg^{-1}$). Pb level in lettuce shoots and roots in pots under field conditions showed that, in AYE, Pb in lettuce shoot (7.16 $mgkg^{-1}$) and root (6.90 $mgkg^{-1}$) were higher than Pb in lettuce shoot (7.05 $mgkg^{-1}$) and root (6.57 $mgkg^{-1}$) in KNUST. Generally, Pb levels in lettuce on dumpsite soils were higher than on background soils and there were significant ($p = 0.01$) difference among the value (Table 4.4).

Cu level in lettuce shoots (10.12 $mgkg^{-1}$) in KYE dumpsite soil was lower than Cu in shoots (11.30 $mgkg^{-1}$) on UEW and higher in roots (12.75 $mgkg^{-1}$) of KYE than in root (10.39 $mgkg^{-1}$) of UEW. On SUA, Cu levels in lettuce shoot (47.70 $mgkg^{-1}$) and root (28.88 $mgkg^{-1}$) were higher than Cu levels in lettuce shoot (11.42 $mgkg^{-1}$) root (9.42 $mgkg^{-1}$) on MED. Cu levels in AYE was higher in lettuce shoot (13.34 $mgkg^{-1}$) but lower in root (9.54 $mgkg^{-1}$) in AYE compare to Cu in lettuce shoot (8.77 $mgkg^{-1}$) and root (10.94 $mgkg^{-1}$) in KNUST. There were a highly significant ($p = 0.01$) differences between all Cu levels in dumpsite soils and background soils (Table 4.4).

Pb level was lower in lettuce shoot (3.75 $mgkg^{-1}$) and higher in lettuce root (3.54 $mgkg^{-1}$) in KYE as compared with in lettuce shoot (3.35 $mgkg^{-1}$) and root (3.23 $mgkg^{-1}$) in UEW. Pb in SUA l lettuce shoot (5.59 $mgkg^{-1}$) and lettuce root (7.99 $mgkg^{-1}$) were both higher than Pb in lettuce shoot (3.53 $mgkg^{-1}$)

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and lettuce root (3.13 mgkg^{-1}) in MED. Pb levels were both higher in lettuce shoot (3.90 mgkg^{-1}) and lettuce root (35.76 mgkg^{-1}) in AYE than Pb concentration levels in KNUST lettuce shoot (3.09 mgkg^{-1}) and lettuce root (3.69 mgkg^{-1}). There were a high significant (p = 0.01) difference between Pb levels in lettuce shoots and roots in dumpsite soils and their background soils showed a highly significantly (p = 0.01) difference (Table 4).

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Table 4.4. Total metal levels in shoots and roots of lettuce in pots under field studies

Treatment	Cu		Pb	
	shoot	root	shoot	root
KYE	10.12	12.75	3.75	3.54
UEW	11.3	10.39	3.35	3.23
SUA	47.70	28.88	5.59	7.99
MED	11.42	9.42	3.53	3.13
AYE	13.34	9.54	3.90	35.76
KNUST	8.77	10.94	3.09	3.69
P - value	0.01	0.01	0.01	0.01
LSD (0.05)	0.83	6.91	0.43	7.67
CV (%)	2.70	27.90	6.00	1.37

Treatments: KYE - Kyeremfaso Mampong dumpsite soil; UEW – Mampong background soil; SUA - Suame Kumasi dumpsite soil; MED - Meduma Kumasi background soil; AYE - Ayeduase Kumasi dumpsite soil; KNUST - KNUST Kumasi botanical gardens background soil.

4.4 Transfer Ratio

TR for Cu in KYE (0.28) was lower than TR for Cu in UEW (0.40). In SUA Cu TR (0.61) was higher than TR for Cu in MED (0.48). In AYE, TR for Cu (0.41) was higher than TR for Cu in KNUST (0.24) (Table 4.5).

TR for Pb in KYE (0.08) was lower than TR for Pb in UEW (0.33). In SUA, Pb TR (0.15) was lower than TR for Pb in (0.39). In AYE, TR for Pb (0.05) was lower than TR for Pb in KNUST (0.31) (Table 4.5).

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Table 4.5. Transfer ratio (TR) values of lettuce in pots under field conditions

Treatment	Transfer ratio	
	Cu	Pb
KYE	0.28	0.08
UEW	0.40	0.33
SUA	0.61	0.15
MED	0.48	0.39
AYE	0.41	0.05
KNUST	0.24	0.31

Treatment: KYE – Kyeremfaso dumpsite soil; UEW – Unuversity of education Mampong background soil; SUA – Suame magazine Kumasi dumpsite soil; MED – Meduma Kumasi background soil; AYE – Ayeduase Kumasi dumpsite soil; KNUST – KNUST botanical gardens Kumasi background soil

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4.5 Evaluation of Heavy Metals Contamination in Selected Soils in Pots

The Geoaccumulation Index (Igeo) of classification by Forstner *et al.* (1993) was used to evaluate the contamination intensity of Cu and Pb.

Cu was 'uncontaminated to moderate' (0.8) in KYE, 'moderate to strong' (2.22) contamination intensity in SUA and 'uncontaminated to moderate' (0.51) in AYE. Cu contamination was in an increasing order of KYE < AYE < SUA. Pb contamination was 'moderate to strong' in KYE (2.55), SUA was 'moderate to strong' (2.65) and 'very strong' AYE (15.69). The order was KYE < SUA < AYE (Table 4.6).

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Table 4.6: Geoaccumulation index (I_{geo}) and contamination intensity for soils in pots under field conditions

	I_{geo} and contamination intensity	
Location	Cu	Pb
KYE	0.8 Uncontaminated to moderate	2.55 Moderate to strong
SUA	2.22 Moderate to strong	2.65 Moderate to strong
AYE	0.61 Uncontaminated to moderate	15.69 Very strong

Location: KYE - Kyeremfaso Mampong dumpsite soil; SUA - Suame Kumasi dumpsite soil; AYE - Ayeduase Kumasi dumpsite soil

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CHAPTER FIVE

5.0 DISCUSSION

5.1 Soil Physicochemical Properties of the Selected Soils at Mampong and Kumasi

The soil physicochemical analytical results generally had improved soil properties on dumpsite soils than on background soils for bulk density, soil pH, total organic matter, total nitrogen, soil available phosphorus and others (Table 4.1) and this could be attributed to the materials emanating from the municipal and metropolis solid and liquid wastes deposited on the soil (Krishna *et al.*, 2016). Soil bulk density results (Table 4.1) were generally lower on the dumpsites than on background soils but were not significantly ($p = 0.88$; $p = 0.64$) different from each other.

The variations in soil pH levels on both dumpsites and background soils (Table 4.1) could be due to differences in biological activities in soils, temperature differences and the disposal of wastes on dumpsites (Oyedele *et al.*, 2008). The higher available phosphorus, exchangeable cations (Ca, Mg, K and Na), EA, CEC and base saturation (Table 4.1) might have come from the wastes found on the dumpsites through decomposition which agrees with a report by Anikwe and Nwobodo (2001) that essential mineral materials from wastes help to increase nitrogen, pH, CEC, base saturation and organic matter level, because dumpsite soils are known to be rich in soil nutrient for plant growth and development (Ogunmodede and Adewole, 2015) as decayed and composted wastes help to enhance soil fertility (Ogunyemi *et al.*, 2003). Higher soil organic matter levels in (Table 4.1) dumpsite soils as compared to background soils was as a result of many organic matter added after decay of organic wastes (Tripathy and Misra, 2012). The high organic matter contents especially in dumpsite soils might have accumulated from subsequent decomposition of plant residue waste materials as reported by Gairola and Soni (2010).

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5.2 Cu Levels in Soils in pots Under Field Conditions

Cu levels were highest in most dumpsites soil than background soils in pots under field conditions (Tables 4.2 and 4.3). Cu an essential metal element was generally higher on dumpsite soils than on their background soils with highly significant ($p = 0.01$) difference between dumpsites and background soils (Tables 4.2 and 4.3). Such Cu levels in dumpsite soils may have been influenced by the natural occurrence of Cu in some soils which is derived from anthropogenic activities such as the use of copper containing fungicides, urban wastes management and industrial activity (Giovani *et al*., 2005). Also, higher Cu concentrations in SUA and AYE may be attributed to higher population and industrial activities in cities and municipalities which could have led to higher production of assorted wastes than in the rural settlements (Agyarko *et al*., 2010). Some of the reasons might also be due to the differences in living standards, consumption patterns and level of industrial development between cities and rural communities (Ebong *et al*., 2008).

Cu levels were highest (78.64 mgkg^{-1}) in SUA (Table 4.2) and 124.23 mgkg^{-1} in SUA (Table 4.3) were, however, above the worlds' scale value of non - polluted soil of 24.00 mgkg^{-1} by Pendias and Pendias (2001); 30.00 mgkg^{-1} (WHO / FAO, 2011) and 100.00 mgkg^{-1} (WHO/FAO, 2001; Shal *et al*., 2011). This is an indication that, the soil from SUA is polluted and might not be suitable for lettuce cultivation.

5.3 Pb Levels in Soils in Pots Under Field Conditions

Pb levels were highest in most dumpsites soil than background soils in pots under field conditions (Tables 4.2 and 4.3). This result showed high Pb levels in KYE which was significantly different ($p = 0.01$) from the Pb in UEW. Also, SUA recorded a higher Pb level than in MED with a significant ($p = 0.01$) difference (Tables 4.2 and 4.3). This observation is expected because of human wastes disposal activities and other Pb sources on dumpsites which may have accumulated Pb leading to an increased level in the dumpsite soils. This pattern bears a resemblance of a Pb concentration trend as observed by Poggio *et al.* (2009) who attributed the differences in Pb levels to numerous activities like mining, melting and manufacturing. The difference in Pb levels may be linked to differences in waste generation between urban and rural population as found by Moller *et al*. (2000).

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The Pb levels in AYE (Table 4.2) and AYE (Table 4.3) were above the worlds' average Pb in unpolluted soils at 44.0 mgkg^{-1} (Kabata - Pendias and Pendias, 2001). This shows that, the soils from AYE may not be suitable for vegetables/crops cultivation.

5.4 Cu levels in lettuce in pots under field conditions

Cu was generally higher in lettuce shoots and roots grown on dumpsite soil than the background soil. A similar results was reported where higher concentrations of heavy metals were detected in fruits and vegetables harvested from waste dumpsites (Imasueb Omorogiera, 2013; Cortez and Ching, 2014; Tanee and Eshalomi - Mario, 2015) because dumpsites mostly used for agriculture are important sources of dangerous heavy metals derived from components of industrial products (Fuge, 2013; Wuana and Okieimen, 2011). Olankule *et al.* (2018) share a similar report that, dumpsites soil may comprise of other materials that contain heavy metals and as a result are of great concern to farmers and consumers in Ghana.

Cu levels were mostly higher in lettuce shoots from most of the study sites than in roots (Table 5.4) which may be related to the fact that, most Cu ions might have been transported from the roots to other parts of lettuce by factors like crop type and soil pH and resulted to higher levels of Cu in lettuce shoots. Gupta *et al.* (2019) share a similar report that, vegetables take up metals from polluted soils and through atmospheric deposition of particulate matter from different sources are first absorbed in the apoplast of roots and transported further into other parts of the plant cells.

Cu level was highest in lettuce shoot (47.70 mgkg^{-1}) and in lettuce root (28.88 mgkg^{-1}) on SUA soil (Table 4.4) were above 11.05 mgkg^{-1}; 5 - 20 mgkg^{-1} as normal range in plants by Radojevic and Bashkin (2006); 8.00 mgkg^{-1} in lettuce by Kabir *et al.* (2011); and 2.5 mgkg^{-1} as normal range in plants by FAO / WHO (2011). These results show that, lettuce shoots and roots cultivated in SUA soil in pots are not safe for human and animals as food or medicinal purposes.

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5.5 Pb levels in Lettuce in pots Under Field Conditions

Pb was mostly high in lettuce roots and shoots on dumpsites soil than on background soils (Table 4.4). This observation is expected because dumpsites soil receives considerable wastes. Zhang *et al.* (2002) affirms this assertion. Pb may have toxic effects on living organisms at certain level of concentration (Ogunmodede and Adewole, 2015). Pb level was high in lettuce shoots but highest in lettuce roots from the cultivated soils (Table 4.4). This finding is supported by an earlier report by Natasa *et al.* (2015) that, different plant parts contain different heavy metals.

Pb value in lettuce shoot (5.59 mgkg^{-1}) cultivated on SUA and the highest Pb level in lettuce root (35.76 mgkg^{-1}) cultivated on AYE (Table 4.4) were above 2.00 mgkg^{-1} in food by FAO / WHO (2011). This result is an indication that, lettuce grown on SUA and AYE are not safe for humans and animal consumption and also for medicinal purposes.

5.6 Transfer Ratio (TR)

In pots study under field conditions, Cu was the least transferred heavy metal in lettuce on KYE (Table 4.5). Cu was the most transferred heavy metal in lettuce on SUA in pots (Table 4.5). Cu and Pb were the most transferred heavy metals in lettuce on UEW compared to KYE (Table 4.5). The transfer ratio (TR) which is the ratio of the concentration of metals in plants to the total concentration of that metal in soil (Hammed *et al*., 2017) were generally higher in lettuce plants on background soils than lettuce plants on dumpsite soils in pots under field conditions. These differences may be due to some other soil factors apart from the total soil metal content which affect the rate of metals uptake by plants which may the subsequently affect transfer ratios of metals in the dumpsite soils. Soil pH, exchangeable cations and cation exchange capacities, climatic change and morphology of the plant. May all affect the transfer ratios Jolly *et al*. (2013) and Chindo *et al*. (2016) share a common view.

In addition, the differences in transfer ratio of metals on the study sites was earlier explained by Cui *et al*. (2004) that, plants species, plants physiological stage, plants metals uptake capacity and growth rates are among the major determinants of metal transfer from soil to the crop, and subsequently might have contributed to the lower transfer ratios of the metals in the dumpsite soils than in background soils. Heavy metals were higher in dumpsite soils (Table 4.2) than in background soils in pots might have contributed

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to lower transfer ratios (Table 4.5) of metals in lettuce plants cultivated on dumpsites soil in pots (Table 4.4) than lettuce cultivated on background soils in pots. This observation conforms to a report that, transfer ratio decreases when plants are grown in soils with higher levels of heavy metals (Natasa *et al*., 2015). Soil pH levels in most dumpsite soils as compare to background soils (Table 4.1) have also contributed to lower transfer ratio of metals in lettuce on dumpsite soils than on background soils because, high soil pH levels in soils have been found to decrease metals mobility in soils. Sheoran *et al*. (2006) confirms this result due to the fact that metal levels decreases at high pH and increases at low pH levels.

5.7 Geoaccumulation Index (I_{geo})

The I_{geo} contamination intensity of Cu and Pb in KYE, AYE and SUA showed contamination intensity of Cu and Pb in increasing order as KYE < AYE < SUA for Cu and AYE < KYE < SUA for Pb (Table 4.6). Pb was least contaminated in KYE and most contaminated in SUA (Table 4.5). The Mampong dumpsite soil was the least polluted with the metals, which may be due to the low population and industrial activities in the area as compared to the order studied sites. Agyarko *et al*. (2010) share a similar result. The various different industrial activities coupled with varying living standards might have contributed to the heavy metals load pollution in the metropolitan dumpsites than in rural set up within a municipal and this results is affirm by Olankule *et al.* (2018).

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CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Soil physicochemical parameters recorded improved levels in dumpsites soils than in background soils at Mampong municipal and Kumasi metropolis.

Dumpsites soils followed a similar pattern with a generally higher Cu and Pb metals level in dumpsites soil than in background soils in pots under field conditions.

Heavy metals level in lettuce shoots and roots were generally higher with metals in lettuce cultivated on dumpsite soils than in background soils. Cu and Pb were above the normal range in lettuce shoot and roots especially in SUA under field conditions.

Evaluation of the geoaccumulation techniques (I_{geo}) at 0 - 15 cm found Cu and Pb were the most intense contaminated metals in SUA; while Pb was intensely contaminated in AYE.

Transfer ratio (TR) values showed higher values for Cu and Pb in the background soil than the dumpsite soil.

6.2 Recommendations

It is suggested that study trials be conducted in other ecological zones within the remaining regions in Ghana to confirm the results in this study. Bio accessibility studies needs to be conducted to confirm if metal contamination of edible plant parts within the farming community could have a negative health impact. Kumasi Suame magazine dumpsite soil which showed higher and above allowable levels of Cu and Pb in soils and plants should be excavated and transported to fill a landfill site designated for hazardous wastes.

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