

**HEAVY METALS CONTAMINATIONS OF SOIL AND WATER AT
AGBOGBLOSHIE SCRAP MARKET, ACCRA**

KNUST



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KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

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DEPARTMENT OF THEORETICAL AND APPLIED BIOLOGY

HEAVY METALS CONTAMINATIONS OF SOIL AND WATER AT
AGBOGBLOSHIE SCRAP MARKET, ACCRA

KNUST

BY

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(BSC. APPLIED CHEMISTRY)

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DECLARATION

I, Boadu Theophilus Marfo do hereby declare that this thesis is a product of a research work I carried out towards the MSc degree except references to other peoples work which have been duly acknowledged, and that neither whole nor part of this thesis has been presented for another degree or programme elsewhere.

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(Supervisor) SIGNATURE DATE

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Rev. S. Akyeampong
(Head of Department) SIGNATURE DATE

DEDICATION

This work is dedicated to my special family: Madam Comfort Okoe, Mr Daniel Boadu-Marfo, Salomey, Isaac (late), Regina, Daniel (junior) and Eric.

Also to mention are my late grandparents Salomey Boateng (Auntie), Opanin Kwasi Marfo and Afia Kwashie (Emaa) for their various roles they played in my life before their demise.

Then finally to Augustina Asantewaa (Wendy) for her constant prayers and encouragement throughout the period of the work.



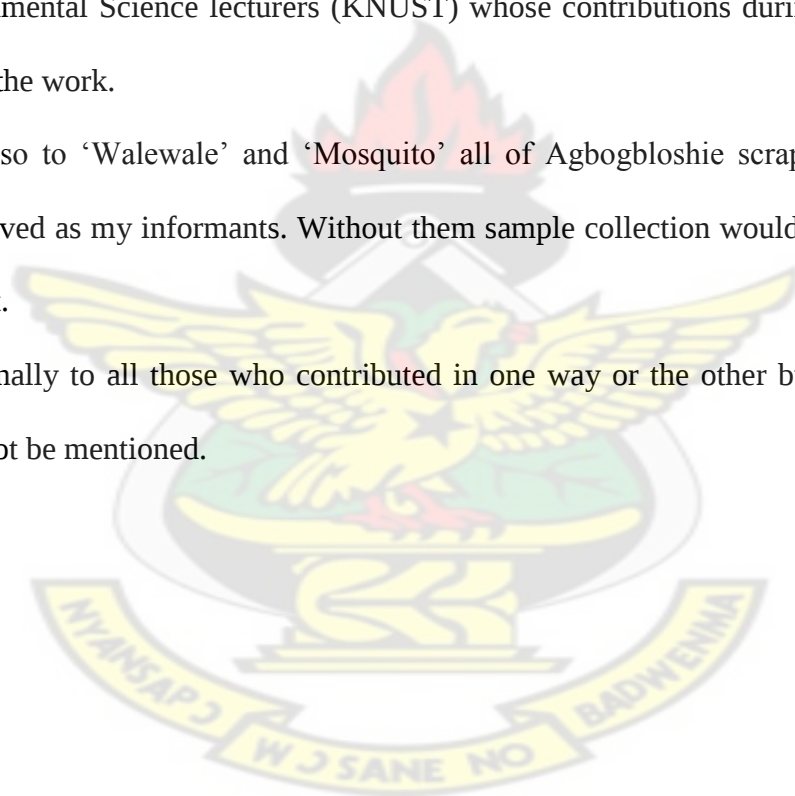
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This work would not have seen the light of day if not for His protection and guidance throughout the entire duration of the research. Thank you God for the strength you gave me throughout this period.

Special thanks to: my supervisor Dr. Samuel Aikins for ensuring consistency and the right thing being done, Prince of ECOLAB and Tsatsu of Soil Science Department (all of Legon) for helping me with the digestion of the samples and the use of the AAS, to all ECOLAB workers, Jacob for drawing the map for me and the entire Environmental Science lecturers (KNUST) whose contributions during presentations shaped the work.

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ABSTRACT

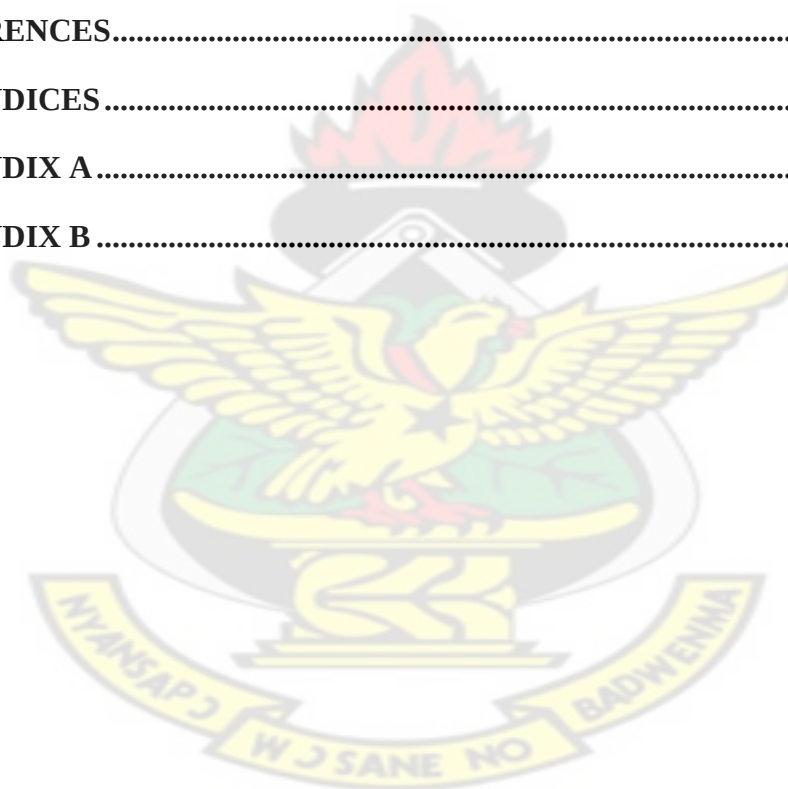
The levels of heavy metals contaminations of both soil and water were investigated at Agbogbloshie scrap market, Accra between December, 2011 and September, 2012. Seven different heavy metals (Zn, Cr, Cu, Cd, Pb, Co and Ni) were measured in eight (8) sampling sites namely 101 (burning site with no disposal), 102 (burning but no disposal), 103 (Big lagoon), 104 (small lagoon), 105 (dismantling site), 106 (no burning or disposal site), 107 (disposal site but no burning) and 108 (disposal and burning site). The sampling sites were considered because of the dismantling and burning of the electronic products to recover metals. Eighteen (18) soil samples and six (6) water samples were used for the study. The soils and water samples collected from the different sites were analyzed at Ecological laboratory of the University of Ghana, Legon. Atomic Absorption Spectrophotometer (AAS) was used for the determination of the heavy metals in the soil and water samples. The mean concentrations of soil samples ranged from 173.60 to 899.90, 9.57 to 57.73, 226.80 to 6291.33, 3.47 to 13.80, 127.83 to 1392.67, 17.03 to 64.43 and 6.47 to 62.53 (mg/kg dry weight) for Zn, Cr, Cu, Cd, Pb, Co and Ni respectively. The contamination levels of Zn, Cu and Pb were high while the rest of the metals (Cr, Cd, Co and Ni) in the soil samples were low. Zn and Pb concentrations exceeded the Dutch target values (Zn: 140 mg/kg and Pb: 85 mg/kg) in all the sampling sites. Their concentrations in site 101 (Zn: 810.53 mg/kg and Pb: 1392.67 mg/kg), 102 (Zn: 899.90 mg/kg and Pb: 642.27 mg/kg) and 105 (Zn: 860.17 mg/kg and Pb: 706.60 mg/kg) were higher than the Dutch intervention values (Zn: 720 mg/kg and Pb: 530 mg/kg). Cu concentration in all the soil samples exceeded the concentration admitted by the Dutch guidelines of the new Dutch list. The Cu concentrations in all the sampling sites for the soils were high. The mean values of the water samples ranged from 0.039 to 0.060, 0 to 0.012, 0.007 to 0.019, 0.069 to 0.074 and 0 to 0.23 (mg/L) for Zn, Cu, Cd, Co and Ni respectively. No Cr and Pb were detected in all the water samples, an indication of lower instrumental detection limit. It was noted that the dismantling and burning of the electronic products to recover metals had a direct impact on the concentrations of the heavy metals determined.

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LIST OF ABBREVIATIONS

Cd	Cadmium.
Cr	Chromium.
Co	Cobalt.
Cu	Copper.
DIV	Dutch Intervention Value.
DTV	Dutch Target Value.
ECOLAB	Ecological Laboratory.
mg/L	Milligram per litre.
mg/kg	Milligram per kilogram.
Ni	Nickel.
NRCS	Natural Resources Conservation Service.
Pb	Lead.
ppm	Parts per million.
PVC	Polyvinylchloride.
SD	Standard deviation.
S (A, B, C, D, E and F)	S = Soil; A, B, C, D, E and F = Site locations.
USDA	United States Department of Agriculture.
W (S and B)	W = Water; S and B = Site location.
WHO	World Health Organization.

CHAPTER ONE

INTRODUCTION

Decomposition of rock and organic matter for many years has resulted in soil formation. Soils as mentioned are critical environments where rock, air and water interface (Facchinelli, 2001). Naturally in soils, chemical elements occur as components of minerals though at certain concentrations some may be toxic. The chemical elements such as metals cannot break down, but their characteristics may change so that they can be easily taken up by plants or animals (Facchinelli, 2001). Bedrock composition, climate, and other factors have led to varying soil properties (Shayley *et al.*, 2009). Soil can be said to be clean where the substance under environmental concern occur in concentrations equal to or lower than the value found in nature which is used as reference and normally called background concentration. The background concentration is the total element concentration obtained from soils that had not been affected by human activity. However, certain actions such as past land use; current activities on the site, and nearness to pollution sources have all affected soil properties (Shayley *et al.*, 2009). Such activities result in contaminations in various forms. According to Worksafe (2005) contamination refers to the condition of land or water where any chemical substance or waste has been added at above background level and represents, or potentially represents, an adverse health or environmental impact. It can result in a potential financial, social and environmental cost (Stavrianou, 2007).

1.1 CONTAMINATED SITE

This is a site that has had one or more certain substances added to it exceeding background levels. The product or the substance may exist in the soil, groundwater or surface water at a concentration which presents a risk of harm to human health or the environment (Stavrianou, 2007). The contaminating substances include heavy metals, solvents, medical waste, fuels, acids, asbestos, oils and hazardous waste (Stavrianou, 2007; Worksafe, 2005). Various channels may be used to identify contaminated sites. This includes contamination: on the surface of the soil or in fill material, deeper in the soil (e.g. covered by soil or fill and not exposed until excavation starts), in surface water, in groundwater, in the air, taken up by vegetation growing on the site and as a result of substances released from existing buildings or plant or during demolition (e.g. asbestos) (Stavrianou, 2007; Worksafe, 2005).

1.2 SOURCES OF CONTAMINATION

Environmental contamination in some developing countries has been attributed to the negative effect of technological developments, such as urbanization and industrialization, with poor planning in waste disposal and management (Bhagure and Mirgane, 2010; Rajaganapathy, 2011; Varalakshmi and Ganeshamurthy, 2010). Sources of contamination include: accidental spills, leaks of chemicals and human activities. Spills, runoff, or aerial deposition of chemicals used for agriculture or industry, materials stored or dumped on the site, contaminants in imported fill and demolition can also result in contamination of the soils and water at residential sites (Shayley *et al.*, 2009; Worksafe, 2005). Also, inadequate disposal practices can result in contamination (Stavrianou, 2007). Activities of humans have added substances such as pesticides, fertilizers and other amendments to soils. Milling operations

together with grinding ores provide a route for contamination in the surface environment (Jung, 2001). Burning of fossil fuel, mining and metallurgy, industries and transport sectors redistribute toxic heavy metals into the environment (Rajaganapathy, 2011; Stavrianou, 2007). The distribution of contaminants released to soils by human activities is related to how and where they are added (Shayley *et al.*, 2009). Also, people can be exposed to contaminants in soil through: ingestion (eating or drinking), dermal exposure (skin contact) or inhalation (breathing), penetration via the skin or eyes (includes exposure to dust) (Shayley *et al.*, 2009; Stavrianou, 2007; Worksafe, 2005). The effect of contaminants is hinged on the chemicals present, the type of exposure and the dose subjected to (Stavrianou, 2007). Soil contaminants can leach from landfills or other garbage disposal sites, including petroleum products, solvents, pesticides, lead, and other heavy metals (Shayley *et al.*, 2009). Contaminants may be introduced into drinking water via runoff or leached from the soil into groundwater. Contaminants vary in their tendency to: end up in water held in the soil or in the underlying groundwater (by leaching through the soil), volatilize (evaporate) into the air and binding tightly to the soil (Shayley *et al.*, 2009). Also, the waste electrical and electronic equipment contains substantial quantities of valuable materials which can be a source of potential environmental contaminants (Wäjer *et al.*, 2011).

1.3 FATE OF CONTAMINANTS

The fate of contaminants can be affected by certain soil characteristics. These characteristics that may affect the behaviour of contaminants include: soil mineralogy and clay content (soil texture), pH (acidity) of the soil, amount of organic matter in the soil, moisture levels, temperature and the presence of other chemicals (Shayley *et*

al., 2009). Certain contaminants are also bioavailable and depend on many characteristics of the soil and of the site. The site conditions affect how tightly the contaminant is held by soil particles and its solubility (Shayley *et al.*, 2009). In aquatic systems, metal contaminants usually remain either in soluble or suspension form and finally tend to settle down to the bottom or are taken by organisms (Aderinola *et al.*, 2009; Ene *et al.*, 2009; Obodai *et al.*, 2011).

1.4 PROBLEM STATEMENT

Industrial revolution followed by the advances in information technology during the last century has radically changed people's lifestyle. But mismanagement has led to new problems of contamination and pollution. It was as a result of this that California passed the Electronic Waste Recycling Act in 2003 which designates electronic waste as hazardous waste which by law cannot be disposed of along municipal waste. Waste Electrical and Electronic Equipment can be both valuable and harmful. This is because it contains valuable materials and also serves as important source of potential environmental contaminants (Wäger *et al.*, 2011). The electronic waste activities are undertaken by men, women and children with little or no consideration to protection of health and the environment. The activities are carried out using environmentally unsound techniques to recycle electronic waste.

1.5 AIM AND OBJECTIVES

The main aim of the research is to assess the levels of the selected heavy metals in both soil and water at Agbogbloshie scrap market, Accra.

Specific objectives of this study are to:

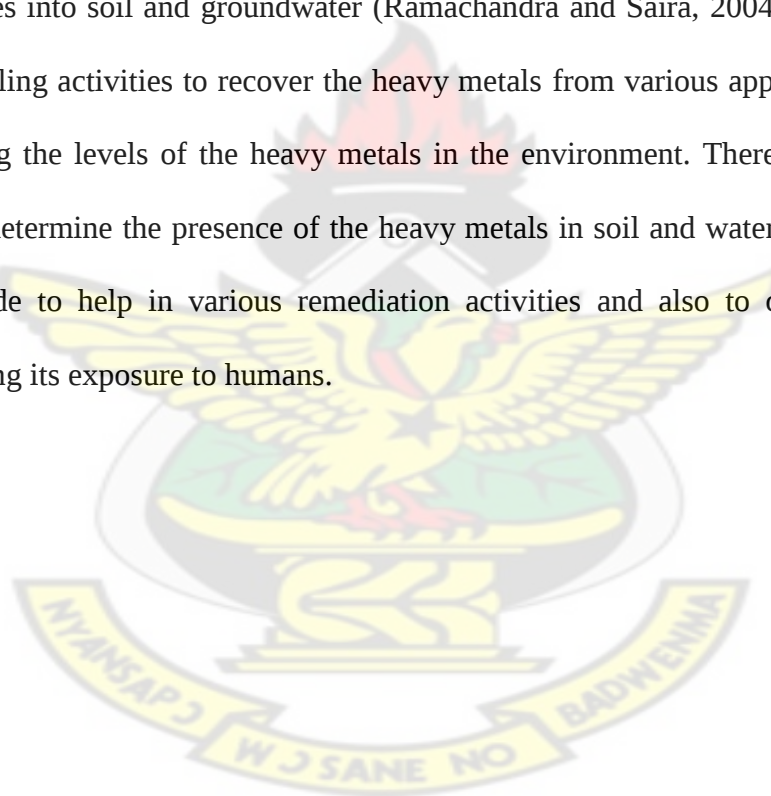
- determine the levels of some selected heavy metals in the soil samples.
- determine the levels of some selected heavy metals in water samples from the lagoon.

1.6 JUSTIFICATION

In mans quest to better lives and make things easier various things are introduced into the environment. This can however lead to environmental contamination affecting both the soil and water as a whole. Contamination refers to the condition of land or water where any chemical substance or waste has been added at above background level and represents, or potentially represents, an adverse health or environmental impact (Worksafe, 2005). Contaminations result from accidental spills, leaks of chemicals and human activities. Spills, runoff, or aerial deposition of chemicals used for agriculture or industry, materials stored or dumped on the site, contaminants in imported fill and demolition can also result in contamination of the soils and water at residential sites (Shayley *et al.*, 2009; Worksafe, 2005). Contaminants including heavy metals may be introduced into drinking water via runoff or leached from the soil into groundwater (El Bouraie *et al.*, 2010). Heavy metals occur naturally in the earth's crust (Aderinola *et al.*, 2009). They are non-biodegradable and tend to be contaminants to living things in the environment (Obodai *et al.*, 2011). Heavy metals persist for a long time in the environment being non degradable and are translocated to different components affecting the biota (Kumar *et al.*, 2010; Obodai *et al.*, 2011; Rajaganapathy, 2011). The persistence of heavy metals can result in bioaccumulation and biomagnifications causing heavier exposure for some organisms than is present in the environment alone (Adelekan and Abegunde, 2011). Heavy metals contamination threatens agriculture and other food sources for human population as well as poor

vegetation growth and lower plant resistance against forests pests. This situation poses a different kind of challenge for remediation. Also, people can be exposed to contaminants in soil through: ingestion (eating or drinking), dermal exposure (skin contact) or inhalation (breathing), penetration via the skin or eyes (includes exposure to dust) (Shayley *et al.*, 2009; Worksafe, 2005). Heavy metal exposure is normally chronic (exposure over a longer period of time), due to food chain transfer. But the case of acute (immediate) poisoning is rare through ingestion or dermal contact, but is possible (Kumar *et al.*, 2010; USDA and NRCS, 2000; Wei and Yang, 2010). The toxicity of heavy metals is one of the major current environmental health concerns and potentially dangerous because of bio-accumulation through the food chain (Rajaganapathy, 2011). Globally, human activities have affected the biogeochemical cycling of heavy metals resulting in a progressive rise in the flux of bioavailable chemical forms to the atmosphere (Yildiz *et al.*, 2010). Through human activities the metals are distributed, concentrated and chemically modified, which may increase their toxicity. The combination of heavy metals with other chemical substance produce dangerous cocktails though very little is known about their combined effects. The presence of heavy metals in water degrades their quality, which eventually affects human health (Rajaganapathy, 2011). Even though some of the heavy metals are useful they also have their adverse effects. The usefulness of the heavy metals can be found in metal alloys and pigments for paints, cement, paper, rubber, and other materials (Lenntech, 2010). They are also used for carbohydrate and lipid metabolism and the utilization of amino acids (Asio, 2009). Also, heavy metals help the body to produce red blood cells and then as an ingredient of steel and other metal products (Asio, 2009; Lenntech, 2010). They are found in re-chargeable nickel-cadmium batteries, pigments,

stabilizers for polyvinyl chloride (PVC), alloys and electronic compounds (Järup, 2003; Wuana and Okieimen, 2011). Finally, they are used in the manufacture of lead storage batteries, solders, bearings, cable covers, ammunition, plumbing, pigments and caulking, production of blood haemoglobin, seed production, disease resistance, and regulation of water (Wuana and Okieimen, 2011). The usefulness of the heavy metals has given credence to its use in various applications. For instance, discarded computers, televisions, stereos, copiers, fax machines, electric lamps, cell phones, audio equipment and batteries if improperly disposed can leach lead and other substances into soil and groundwater (Ramachandra and Saira, 2004). This increases the recycling activities to recover the heavy metals from various appliances. Thereby increasing the levels of the heavy metals in the environment. There is therefore the need to determine the presence of the heavy metals in soil and water. This will serve as a guide to help in various remediation activities and also to create awareness concerning its exposure to humans.



CHAPTER TWO

LITERATURE REVIEW

2.1 HEAVY METALS

Several meanings have been assigned to heavy metals. Heavy metals can also be loosely defined as a subset of elements that exhibit metallic properties. It comprises the transition metals, some metalloids, lanthanides, and actinides. Using density as a defining factor, Järup (2003) also defined heavy metals as those having a specific density of more than 5 g/cm^3 (Suciu *et al.*, 2008). They can also be chemical elements with the density greater than 4 g/cm^3 found in all kinds of soils, rocks and water in terrestrial and freshwater ecosystem (Adelekan and Abegunde, 2011). Heavy metals can be said to be referred to as any metallic element that has a relatively high density and is toxic or poisonous even at low concentration (Lenntech, 2010; Obodai *et al.*, 2011; Yahaya *et al.*, 2012). Therefore, heavy metals are chemical elements with a specific gravity that is at least 5 times the specific gravity of water. The specific gravity of water is 1 at 4°C (39°F). The specific gravity can also be defined as a measure of density of a given amount of a solid substance when it is compared to an equal amount of water. Another school of thought also put heavy metals as having a density of 6.0 g/cm^3 or more (much higher than the average particle density of soils which is 2.65 g/cm^3) and occur naturally in rocks but concentrations are frequently elevated as a result of contamination (Asio, 2009). They can also be said to be intrinsic, natural constituents of our environments (Aderinola *et al.*, 2009). Therefore they can be said to be a group of metals and metalloids with atomic density greater than 4 g/cm^3 or 5 times or greater than water (Obodai *et al.*, 2011; Yahaya *et al.*, 2012).

2.2 SOURCES OF HEAVY METALS IN CONTAMINATED SOILS AND WATERS

Largely, within the European community the eleven elements of highest concern are arsenic, cadmium, cobalt, chromium, copper, mercury, manganese, nickel, lead, tin, and thallium. Metals occur naturally in our environment, but rarely at toxic levels, especially in the Earth's crust, where they contribute to the balance of the planet (Kumar *et al.*, 2010; Obodai *et al.*, 2011; USDA and NRSC, 2000). Generally, metals enter the aquatic environment through atmospheric deposition, erosion of geological milieu or due to anthropogenic activities caused by industrial effluents, domestic sewage and mining waste (Adelekan and Abegunde, 2011; Aderinola *et al.*, 2009; Bhagure and Mirgane, 2010; Ene *et al.*, 2009; Obodai *et al.*, 2011). Then also through urban storm, water runoff, landfill, mining of coal and ore. But naturally metals get to waters by chemical weathering of minerals and soil leaching (El Bouraie *et al.*, 2010). Heavy metals are always present at background levels of non-anthropogenic origin where their source in soils could be related to weathering of parent rocks and pedogenesis (Facchinelli, 2001). Heavy metals occur naturally in the ecosystem with large variations in concentration (Şerban, 2000). Though in very low concentrations traces of heavy metals are not toxic in plants and animals there are few exceptions. For instance, lead, cadmium and mercury are toxic at very low concentrations (Suciu *et al.*, 2008). Since the middle of the 19th century, productions of heavy metals have increased steeply for more than 100 years, with concomitant emissions to the environment (Järup, 2003). Emission of heavy metals to the environment occur via a wide range of processes and pathways, including to the air (e.g. during combustion, extraction and processing), to surface waters (via runoff and releases from storage and transport) and to the soil (and hence into groundwaters and crops) (El Bouraie *et al.*,

2010; Järup, 2003). Heavy metals contamination can result from various sources such as purification of metals. For instance, the smelting of copper, the preparation of nuclear fuels and electroplating which produces chromium and cadmium (Ene *et al.*, 2009). Other sources of heavy metals can be from dead and decomposing vegetation, animal matter, wet and dry fallouts of atmospheric particulate matters and from man's activities (Obodai *et al.*, 2011; Wufem, 2009). Yildiz *et al.* (2010) reported on anthropogenic sources which lead to accumulation of heavy metals such as lead (Pb), zinc (Zn), copper (Cu) and nickel (Ni) in the environment (Nassef *et al.*, 2006). Such activities which give rise to the heavy metals include the burning of coal and oil, steel works, smelting procedures, cement industry and mining operations (Dávila *et al.*, 2012; Obodai *et al.*, 2011; Suciú *et al.*, 2008). Heavy metal contamination of arable soils is primarily caused by wastewater from mines being used to irrigate paddy fields (Adelekan and Abegunde, 2011), by emissions from nonferrous metal refineries (Ene *et al.*, 2009), land application of fertilizers (El Bouraie *et al.*, 2010), animal manures (El Bouraie *et al.*, 2010), sewage sludge (Adelekan and Abegunde, 2011), pesticides (El Bouraie *et al.*, 2010) and coal combustion residues (El Bouraie *et al.*, 2010). If there are no proper treatments or disposal of mine tailings and mine drainage then agricultural fields can be contaminated (Makino *et al.*, 2010; Wuana and Okieimen, 2011). Also manufacturing and the use of synthetic products (e.g. pesticides, paints, batteries, industrial waste and land application of industrial or domestic sludge) can result in heavy metal contamination of urban and agricultural soils (USDA and NRCS, 2000; Wei and Yang, 2010). Another important source of heavy metal contamination is human transport either by land, air, inland water or sea. The heavy metals in the aquatic environment can be found in sediments and suspended particulates ($>0.45\mu\text{m}$) (Aderinola *et al.*, 2009; Wufem, 2009). Anthropogenic

sources such as mining and metallurgy, manufacturing, agriculture, industrial waste water discharges, sewage wastewater, fossil fuel combustion and atmospheric deposition and transport sectors can also introduce heavy metals into water bodies such as rivers and lagoons thereby contaminating them (Ene *et al.*, 2009; Varalakshmi and Ganeshamurthy, 2010). The metals dissolve and move downstream to lower reaches of the water bodies while others settle into the sediments (Kumar *et al.*, 2010; Obodai *et al.*, 2011; Oluyemi *et al.*, 2010; Rajaganapathy, 2011; Suciu *et al.*, 2008). Mention must be made that the specific type of metal contamination found in a contaminated soil is directly related to the operation that occurred at the site. The range of contaminant concentrations and the physical and chemical forms of contaminants will also depend on activities and disposal patterns for contaminated waste on the site. Certain factors that may have effect on the form, concentration, and distribution of contaminants include soil and ground-water chemistry and local transport mechanisms (Wuana and Okieimen, 2011).

2.3 PROPERTIES OF HEAVY METALS

Heavy metals have the ability to enter the human body through inhalation, ingestion and dermal contact absorption (Adelekan and Abegunde, 2011; Rajaganapathy, 2011; Wei and Yang, 2010). They also accumulate in soils, plants and in aquatic biota (Obodai *et al.*, 2011; Suciu *et al.*, 2008; Wuana and Okieimen, 2011). Heavy metals can persist for a long time within different organic and inorganic colloids before becoming available to living organisms (Adelekan and Abegunde, 2011; Friedlova, 2010). They are non degradable and therefore do not decay with time. Heavy metals can be biomagnified if an organism excretes it slower than it takes in. They can therefore become dangerous to human beings and wildlife (Adelekan and Abegunde,

2011; Facchinelli, 2001; Kumar *et al.*, 2010). They also have relatively high densities (Lenntech, 2010; Obodai *et al.*, 2011). Apart from having high densities, heavy metals occur near the bottom of the periodic table (Facchinelli, 2001; Obodai *et al.*, 2011; Rajaganapathy, 2011). Heavy metals bioaccumulate and tend to be dangerous since they have long biological half lives (Aderinola *et al.*, 2009; Lenntech, 2010; Obodai *et al.*, 2011; Rajaganapathy, 2011). They also occur as cations which strongly interact with the soil matrix.

2.4 EFFECTS OF HEAVY METALS

Heavy metals can be described as contaminants in the soil environment because (i) through man-made cycles their rates of generation are more rapid relative to natural ones, (ii) they become transferred from mines to random environmental locations where higher potentials of direct exposure occur, (iii) compared to those in the receiving environment the concentrations of the metals in discarded products are relatively high, and (iv) the chemical form (species) in which a metal is found in the receiving environmental system may render it more bioavailable (Wuana and Okieimen, 2011). Occurring as natural constituents of the earth's crust, heavy metals are by nature non-biodegradable and tend to be contaminants to living things in the environment (Aderinola *et al.*, 2009; Bhagure and Mirgane, 2010; Obodai *et al.*, 2011). Therefore, the biota that inhabits contaminated sites is exposed to very high amounts of the heavy metals (Aderinola *et al.*, 2009). Environmental problems can also result from irrigation with sewage effluent which introduces heavy metals though can help alleviate water shortages (Makino *et al.*, 2010).

Heavy metals contamination threatens agriculture and other food sources for human population as well as poor vegetation growth and lower plant resistance against forests pests. Thereby having impact on the quality of food, groundwater, microorganisms and plant growth (Ene *et al.*, 2009). Their effect on microorganisms can give rise to decrease in litter decomposition and nitrogen fixation, less efficient nutrient cycling and impair enzyme synthesis (Adelekan and Abegunde, 2011). Heavy metals persist for a long time in the environment being non degradable and are translocated to different components affecting the biota (Kumar *et al.*, 2010; Obodai *et al.*, 2011; Rajaganapathy, 2011). This situation poses a different kind of challenge for remediation. The persistence of heavy metals can result in bioaccumulation and biomagnifications causing heavier exposure for some organisms than is present in the environment alone (Bhagure and Mirgane, 2010). For instance, mercury and selenium can be transformed and volatilized by microorganisms (USDA and NRCS, 2000). According to Yildiz *et al.* (2010), increasing exposure to toxic elements in marine and terrestrial organisms can have adverse toxicological effects. For instance, Coastal fish (such as the smooth toadfish) and seabirds (such as the Atlantic Puffin) are often monitored for the presence of such contaminants. Mention can also be made of Minamata disease and itai-itai disease from mercury and cadmium poisonings respectively (Azimi *et al.*, 2006). Heavy metal exposure is normally chronic (exposure over a longer period of time), due to food chain transfer. But the case of acute (immediate) poisoning is rare through ingestion or dermal contact, but is possible (Adelekan and Abegunde, 2011; Kumar *et al.*, 2010; USDA and NRCS, 2000; Wei and Yang, 2010).

Heavy metals being highly toxic can cause damaging effects even at very low concentrations (Yahaya *et al.*, 2012). The toxicity of heavy metals is one of the major current environmental health concerns and potentially dangerous because of bioaccumulation through the food chain (Adelekan and Abegunde, 2011; Rajaganapathy, 2011). Globally, human activities have affected the biogeochemical cycling of heavy metals resulting in a progressive rise in the flux of bioavailable chemical forms to the atmosphere (Yildiz *et al.*, 2010). Through human activities the metals are distributed, concentrated and chemically modified, which may increase their toxicity. The activities however can result in higher concentrations of the metals relative to their normal background values (Adelekan and Abegunde, 2011). The combination of heavy metals with other chemical substance produce dangerous cocktails though very little is known about their combined effects. The presence of heavy metals in water degrades their quality, which eventually affects human health (Adelekan and Abegunde, 2011; Rajaganapathy, 2011).

2.5 HEAVY METAL TRANSPORT

Generally, heavy metals enter into the body system through air, food and water and bioaccumulate over a period of time (Lenntech, 2010; Obodai *et al.*, 2011). Bioaccumulation means an increase in the concentration of a chemical in a biological organism over time, compared to the chemical's concentration in the environment (Lenntech, 2010). Emission of heavy metals to the environment occur via a wide range of processes and pathways, including to the air (e.g. during combustion, extraction and processing), to surface waters (via runoff and releases from storage and transport) and to the soil (and hence into ground waters and crops) (Järup, 2003). Certain contaminants move through the air and deposited as dust or by precipitation.

Heavy metals enter the aquatic environment through atmospheric deposition. They usually remain either in soluble or suspension form and finally tend to settle down to the bottom or are taken up by organisms (Obodai *et al.*, 2011). Sediments are hosts of toxic metals and can therefore allow for the detection of heavy metals that may be either absent or in low concentration in the water column (Aderinola *et al.*, 2009). The accumulated heavy metals in the sediments can remain present for many years. Also chemicals may be carried by winds and deposited on the surface of soils (Shayley *et al.*, 2009). Dietary intake of food may constitute a major source of long-term low-level body accumulation of heavy metals (Doherty *et al.*, 2011).

2.6 USES OF HEAVY METALS

Heavy metals have varied uses, even though in certain concentrations they tend to be dangerous. Some of its uses are as follows:

- Chromium is used in metal alloys and pigments for paints, cement, paper, rubber, and other materials (Lenntech, 2010). Chromium is required for carbohydrate and lipid metabolism and the utilization of amino acids (Asio, 2009).
- In small amounts nickel can be used by the body to produce red blood cells and then as an ingredient of steel and other metal products (Asio, 2009; Lenntech, 2010).
- Cadmium compounds are used in re-chargeable nickel-cadmium batteries, pigments, stabilizers for polyvinyl chloride (PVC), alloys and electronic compounds (Järup, 2003; Wuana and Okieimen, 2011).

- Lead is also used in the manufacture of lead storage batteries, solders, bearings, cable covers, ammunition, plumbing, pigments and caulking (Wuana and Okieimen, 2011).
- Copper is also used in the production of blood haemoglobin, seed dressing, disease resistance, and regulation of water (Wuana and Okieimen, 2011).

2.7 SELECTED HEAVY METALS

The heavy metals to be determined in both the soil and the water samples were zinc (Zn), chromium (Cr), copper (Cu), cadmium (Cd), lead (Pb), cobalt (Co) and nickel (Ni).

2.8 Zinc (Zn)

Zinc (Zn) is a hexagonal crystal, bluish-white metal and a d-block metal. It is a transition metal located in period 4 and group 12. It also has atomic number 30, atomic mass 65.4, density 7.15 g/cm³, melting point 693 K and a boiling point of 1180 K. Zinc (Zn) is actually a common element found in air, soil, water and all foods (Hardy *et al*, 2008). It occurs naturally in soil but the concentrations are rising due to anthropogenic additions. Most additions are from industrial activities such as mining, coal, waste combustion and steel processing (Wuana and Okieimen, 2011). Then also from the use of liquid manure, composted materials, fertilizers and pesticides in agriculture (Bhagure and Mirgane, 2010). It is used in industry to make paint, dye, rubber, wood preservatives and as well as ointments (Hardy *et al.*, 2008). Zinc (Zn) pollutes water due to the large quantities present in the wastewater of industrial plants and the water-soluble forms present in the soil can contaminate groundwater. It may

increase the acidity of waters. Then can negatively influence the activity of microorganisms and earthworms thereby retarding the breakdown of organic matter (Wuana and Okieimen, 2011).

2.9 Chromium (Cr)

Chromium (Cr) is a cubic crystal, steel gray, very hard and a d-block metal. It is a transition metal which belongs to period 4 and group 6. On the periodic table chromium (Cr) has atomic number 24, atomic mass 52, density 7.19 g/cm^3 , melting point 2130 K and boiling point 2755 K. It does not occur naturally in elemental form but only in compounds (Wuana and Okieimen, 2011). Chromium (Cr) as a primary ore product is mined in the form of mineral chromite, FeCr_2O_4 (Hardy *et al.*, 2008). Sources of chromium (Cr) contamination include releases from electroplating processes and disposal of chromium (Cr) containing waste. Chromium (VI) is the form of Cr commonly found at contaminated sites and toxic levels are common in soils applied with sewage sludge (Asio, 2009; Wuana and Okieimen, 2011). It can be reduced to Cr (III) by soil organic matter (Wuana and Okieimen, 2011). It can be transported by surface runoff to surface waters in its soluble or precipitated form. Most of chromium (Cr) released into natural waters is particle associated and ultimately deposited into the sediment. Chromium (Cr) is required for carbohydrate and lipid metabolism, utilization of amino acids and as pigments for paints, cement, paper, rubber, metal plating for prevention of corrosion, leather tanning and textile colour pigments (Asio, 2009; Bhagure and Mirgane, 2010; Hardy *et al.*, 2008; Lenntech, 2010). It also contributes in maintaining a normal glucose tolerance factor (Bhagure and Mirgane, 2010). Exposure to chromium (Cr) can lead to allergic dermatitis in humans, bleeding of the gastrointestinal tract, cancer of the respiratory

tract and ulcers of the skin. Then also damage to the mucus membrane, liver and kidney damage (Adelekan and Abegunde, 2011; Bhagure and Mirgane, 2010).

2.10 Copper (Cu)

Copper (Cu) is a cubic crystal, reddish and a d-block metal. It is also a transition metal located in period 4 and group 11. Copper (Cu) has atomic number 29, atomic mass 63.5, density 8.96 g/cm³, melting point 1357 K and boiling point 2840 K. It occurs in rocks, soil, water, air, plants and animals (Hardy *et al*, 2008). It is also an essential micronutrient required in the growth of both plants and animals. Concerning humans copper (Cu) helps in the production of blood haemoglobin whiles in plants it is used in seed production, disease resistance and regulation of water (Wuana and Okieimen, 2011). It is also used as a component in metal alloys, electrical wiring, preservatives for wood, leather and fabrics (Hardy *et al*, 2008). Copper (Cu) is not magnified in the body or bioaccumulate in the food chain. High doses of copper cause anaemia, liver and kidney damage, stomach and intestinal irritation, neurological complications, hypertension and liver and kidney dysfunctions (Bhagure and Mirgane, 2010; Lenntech, 2010; Wuana and Okieimen, 2011). It can also be described as a toxic waste and therefore unpalatable for consumption (Adelekan and Abegunde, 2011)

2.11 Cadmium (Cd)

Cadmium (Cd) is also a hexagonal crystal, silver white malleable and a d-block metal. This is a transition metal belonging to period 5 and group 12. It has atomic number 48, atomic mass 112.2, density 8.65 g/cm³, melting point 594 K and boiling point of 1038 K. It is an essential micronutrient for plants and animals but may cause

malfunctioning of metabolic processes (Wuana and Okieimen, 2011). Cadmium (Cd) enters the environment through the uncontrolled burning of coal and garbage and through the human's food chain directly or indirectly from plants or animals (Azimi *et al.*, 2006). The application of agricultural inputs such as fertilizers, pesticides, biosolids (sewage sludge), and the disposal of industrial waste and the deposition of atmospheric contaminants increases the total concentration of Cd (Asio, 2009; Järup, 2003; Wuana and Okieimen, 2011). It can also result from burning of fossil fuels, sewage sludge, plastics waste, byproduct of Zn and lead refining, insecticides and motor oil (Asio, 2009; (Bhagure and Mirgane, 2010; Järup, 2003). Cadmium (Cd) uses include Ni/Cd batteries, pigments, stabilizers for polyvinyl chloride (PVC), in alloys, electronic compounds, barriers to control nuclear fission, phosphors in the production of televisions, anticorrosive coatings for metals, amalgam in dentistry and worm treatments for swine and poultry (Hardy *et al.*, 2008). Cadmium (Cd) causes bone diseases (itai- itai), cardiovascular diseases, renal problems, severe pains in the joints, kidney and lung problems and also anaemia due to decrease of iron adsorption by intestines (Adelekan and Abegunde, 2011; Azimi *et al.*, 2006; Bhagure and Mirgane, 2010; Hardy *et al.*, 2008). The first indicator of cadmium poison is the malfunctioning of the kidneys (Azimi *et al.*, 2006). It affects sperm, reduces birth weight and a causal factor in cardiovascular diseases and hypertension (Adelekan and Abegunde, 2011; Asio, 2009). Also Cd exposure can lead to situations such as neurotoxin, hypertension, carcinogenic, teratogenic, liver dysfunction, nausea, vomiting, respiratory difficulties, cramps and loss of consciousness (Adelekan and Abegunde, 2011; Bhagure and Mirgane, 2010).

2.12 Lead (Pb)

Lead (Pb) is cubic crystal, silver blue-white, soft and a p-block metal. It is located in period 6 and group 14. Lead has atomic number 82, atomic mass 207.2, density 11.4 g/cm³, melting point 601 K and boiling point 2013 K. According to Wuana and Okieimen (2011) lead is a naturally occurring and found as a mineral combined with other elements such as sulphur (PbS, PbSO₄) and oxygen (PbCO₃). Also waste incineration contributes to a greater amount of lead available in urban areas. Its uses include storage batteries, solders, bearings, cable covers, ammunition, plumbing, pigments, caulking, sound and vibration absorbers (Hardy *et al*, 2008). The two routes of exposure to lead come from inhalation and ingestion and the effects from both are the same (Wuana and Okieimen, 2011). Lead (Pb) accumulation in the body organs (i.e, brain) may lead to poisoning (plumbism) or even death. The presence of lead (Pb) may also affect the gastrointestinal tract, kidneys, and the central nervous system. For instance, children exposed to lead (Pb) suffer from impaired development, lower IQ, shortened attention span, hyperactivity and mental deterioration. Those at substantial risk are the children under the age of six (Asio, 2009; Hardy *et al.*, 2008; Wuana and Okieimen, 2011). Then in the case of adults' decreased reaction time, loss of memory, nausea, insomnia, anorexia, weakness of the joints, failures of reproduction, inhibition of haem synthesis, irritation, and producing tumour are all caused by exposure to lead (Adelekan and Abegunde, 2011; Asio, 2009).

2.13 Cobalt (Co)

Cobalt (Co) is cubic crystal, silver gray and a d-block metal. It is also a transition metal located on the periodic table in period 4 and group 9. It has atomic number 27, atomic mass 58.9, density 8.9 g/cm³, melting point 1768 K and boiling point 3143 K. There are three valence states of cobalt namely 0, +2 and +3 (Kim *et al.*, 2006). In nature, it is frequently associated with nickel, and both are characteristic minor components of meteoric iron. Cobalt exposure can be both natural and anthropogenic. The natural sources result from wind-blown dust, seawater spray, volcanoes, forest fires, and continental and marine biogenic emissions. Also, the anthropogenic sources can be from burning of fossil fuels, sewage sludge, phosphate fertilizers, mining and smelting of cobalt ores, processing of cobalt alloys, and industries that use or process cobalt compounds (Kim *et al.*, 2006). Having released into the atmosphere cobalt is deposited on soil, but in water may sorb to particles and settle into sediment or sorb directly to sediment. Cobalt (Co) can be used in electroplating, as a ground coats for porcelain enamels, magnetic steels, some types of stainless steels and alloys for jet engines and gas turbines. Concerning humans, cobalt is important because it is part of vitamin B12, which is essential component for human health (Bhagure and Mirgane, 2010). It is also used to treat anaemia with pregnant women because it stimulates the production of red blood cells (Lenntech, 2012). Among individuals who are iron deficient there is an observable increase in cobalt absorption (Kim *et al.*, 2006). Inhalation and dermal exposure to cobalt in humans can result in bronchial asthma, interstitial lung disease, lung cancer, pneumonia, heart problems, thyroid damage, nausea, vomiting and diarrhoea (Bhagure and Mirgane, 2010; Kim *et al.*, 2006; Lenntech, 2012). Then in animals exposure to cobalt could cause reproductive and developmental effects (Kim *et al.*, 2006).

2.14 Nickel (Ni)

Nickel (Ni) is also cubic crystal, silvery and a d-block metal. This is a transition metal belonging to period 4 and group 10. It has atomic number 28, atomic mass 58.7, density 8.9 g/cm³, melting point 1726 K and boiling point of 3005 K. It is an element that occurs in the environment only at very low levels and is essential in small doses, but it can be dangerous when the maximum tolerable amounts are exceeded (Asio, 2009; Wuana and Okieimen, 2011). Nickel contaminations in the soil are metal plating industries, combustion of fossil fuels, nickel mining and electroplating (Bhagure and Mirgane, 2010). Humans may also be exposed to nickel (Ni) by inhalation, drinking water, and eating contaminated food (Asio, 2009). It is released into the air by power plants and trash incinerators and settles to the ground after undergoing precipitation reactions. Nickel can also end up in surface water when it is a part of wastewater streams (Wuana and Okieimen, 2011). It is used in the manufacture of stainless steel, coins, nickel for armor plates, burglarproof vaults, vegetable oils, ceramics and Ni-Cd batteries (Asio, 2009; Hardy *et al.*, 2008). Nickel (Ni) can result in lung, liver and kidney damage. In high quantities Ni can also cause cancer, respiratory failure, birth defects, allergies, dermatitis, eczema, nervous system and heart failure (Adelekan and Abegunde, 2011; Asio, 2009; Lenntech, 2010).

2.15 PREVENTION/SOLUTION

Introduction of heavy metals into the environment contaminates it because they persist for a long time and do not degrade (Kumar *et al.*, 2010; Obodai *et al.*, 2011; Rajaganapathy, 2011).

But the only exceptions are mercury and selenium, which can be transformed and volatilized by microorganisms (USDA and NRCS, 2000). In terms of contaminated

soils, remediation entails knowledge of the source of contamination, basic chemistry, and environmental and associated health effects of these heavy metals (Wuana and Okieimen, 2011). When large areas of soil are contaminated then certain treatments for heavy metal contamination become very expensive. The treatments can be done either in situ (on-site), or ex situ (removed and treated off-site) (Wuana and Okieimen, 2011). Some decontamination techniques include high temperature treatments (produce a vitrified, granular, non-leachable material), solidifying agents (produce cement-like material) and washing process (leaches out contamination) (USDA and NRCS, 2000; Wuana and Okieimen, 2011). Apart from the traditional ways of remediating heavy metal contaminated soils, other management practices can also be applied.

2.16 MANAGEMENT OF HEAVY METAL CONTAMINATED SOILS

Although the management practices will not remove the heavy metal contaminants, immobilization of the metals in the soil can help reduce the potential adverse effects from the metals (USDA and NRCS, 2000).

The following can help to achieve the management practices;

i. The pH of 6.5 or higher.

At lower pH levels cationic metals are more soluble and therefore available to plants.

Increasing the pH makes the metals less soluble and therefore less likely to be incorporated in their tissues and ingested by humans. The converse also holds for anionic elements (USDA and NRCS, 2000).

ii. Drainage.

Drainage enhances soil aeration and will allow heavy metals to oxidize, making them less soluble and less available. Exception is chromium, which then becomes more available in oxidized forms. The availability of chromium can be addressed by applying active organic matter (USDA and NRCS, 2000).

iii. Phosphate application

Increasing levels of phosphate applied to the soil will decrease the availability of cationic metals. However, the opposite is true for anionic compounds such as arsenic. It is also to note that over-application of phosphorus in the soil can result in water pollution (USDA and NRCS, 2000).

iv. Use of plants on heavy metal contaminated soils.

Translocation of greater number of heavy metals in plants is to the leaves than to their fruits or seeds. Therefore, there is a greater risk in leafy vegetables such as lettuce or spinach and forage eaten by livestock (USDA and NRCS, 2000). Certain plants have been used for treating heavy metal contaminated soils.

Plants are very effective in cleaning up heavy metal contaminated soils by absorption. Crops absorb heavy metals along with other essential plant nutrients (Dávila *et al.*, 2012; Varalakshmi and Ganeshamurthy, 2010). The process can be achieved through phytoremediation. Phytoremediation is using plants to remove, degrade, or contain soil pollutants such as heavy metals, pesticides, solvents, crude oil, polyaromatic hydrocarbons, and landfill leachates. For instance, prairie grasses can stimulate breakdown of petroleum products. Then wildflowers were used to degrade hydrocarbons from an oil spill in Kuwait (USDA and NRCS, 2000; Wuana and Okieimen, 2011). In most cases, trees are used for remediation. The reason being that they are the lowest cost plant type, can grow on land of marginal quality and have

long life-spans. Their usage is as a result of the fact that they need little or no maintenance costs. Some trees used are willows and poplars which have a high flood tolerance. Advantages that can be obtained from this treatment option include aesthetic beauty, decrease of water infiltration and leaching of contaminants. But there are also certain disadvantages that go with this treatment option. For instance, if the chosen plants refuse to grow in highly contaminated areas. Then also they may take years to reach regulatory levels resulting in long-term maintenance. There is also a situation where contaminants below the rooting depth may not be extracted. Apart from this, plants grown on contaminated water and soils become a potential threat to human and animal health.

In order to stabilize or remove metals from soil and water certain mechanisms are involved. The mechanisms include rhizofiltration, phytoextraction and phytostabilization (USDA and NRCS, 2000; Wuana and Okieimen, 2011).

2.17 RHIZOFILTRATION

This uses hydroponically cultivated plants roots to remediate contaminated water through absorption, concentration and precipitation of pollutants. The heavy metals are adsorbed onto plant roots or absorbed into plant roots and must be in the form of solution surrounding the root zone (rhizosphere) (USDA and NRCS, 2000; Wuana and Okieimen, 2011). This mechanism can be used to decontaminate groundwater where plants are grown in greenhouses in water instead of soil. In this process contaminated water is either collected from a waste site or brought to the plants, or the plants are planted in the contaminated area, where the roots then take up the water and the contaminants dissolved in it (USDA and NRCS, 2000; Wuana and Okieimen, 2011). The process removes the contaminants by trapping them into harvestable plant

biomass. When this is done the saturated roots with the heavy metal contaminants are then harvested including the roots (USDA and NRCS, 2000; Wuana and Okieimen, 2011). Rhizofiltration is similar to phytoextraction in a way that both concentrates and precipitates heavy metals than organic contaminants. The only difference between them is that whiles rhizofiltration is used for treatment in aquatic environments phytoextraction deals with soil remediation.

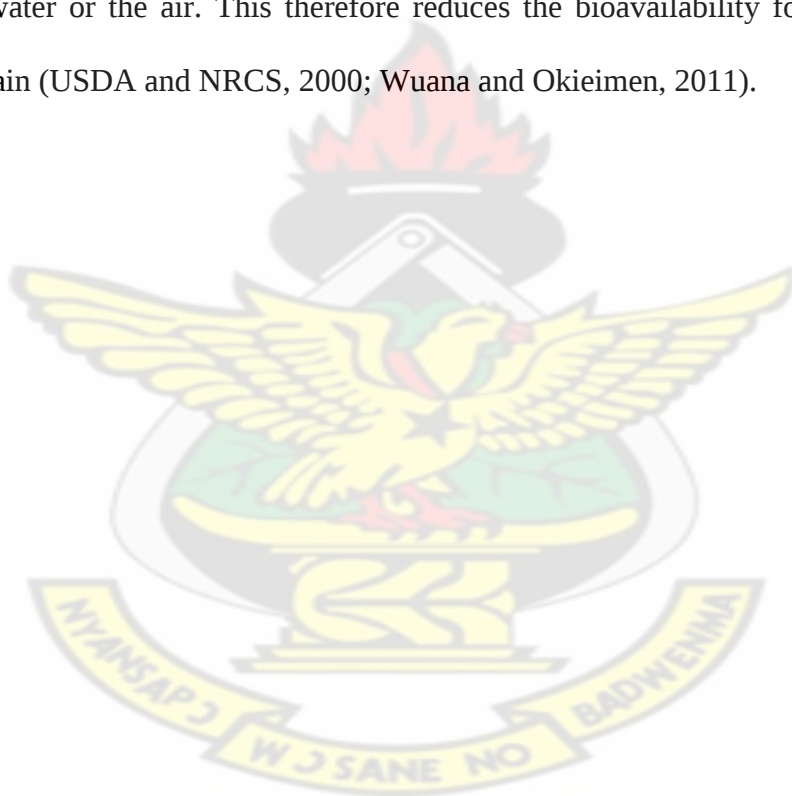
2.18 PHYTOEXTRACTION

This is also where plants are grown in heavy metal contaminated soils. The plant roots then translocate the heavy metals into above ground portions of the plant. Having grown for sometime they are harvested and incinerated or composted to recycle the heavy metals. The incinerated plants in the form of ash are then disposed of in a hazardous landfill (USDA and NRCS, 2000)

Also, phytoextraction is done with plants called hyperaccumulators which absorb unusually large amounts of heavy metals in comparison to other plants (USDA and NRCS, 2000; Wuana and Okieimen, 2011). The problem with hyperaccumulators is that they are slow growing, produce low biomass and needs years to clean up heavy metal contaminated sites (Wuana and Okieimen, 2011). For instance, hyperaccumulator Alpine pennycress (*Thlaspi caerulescens*), *Ipomea alpine* etc., can be made to take up heavy metals like zinc, cadmium and copper in the soils (USDA and NRCS, 2000; Wuana and Okieimen, 2011).

2.19 PHYTOSTABILIZATION

In this case, perennial, non-harvested plants are used to stabilize or immobilize heavy metal contaminants in the soil and groundwater. The heavy metals can be absorbed and accumulated by roots, adsorbed onto roots, or precipitated within the rhizosphere (USDA and NRCS, 2000; Wuana and Okieimen, 2011). Where natural vegetation is lacking heavy metal-tolerant plants can be used to restore vegetation. This in a way reduces the risk of water, wind erosion and leaching. Phytostabilization reduces the mobility of the heavy metal contaminants and prevents further movement into groundwater or the air. This therefore reduces the bioavailability for entry into the food chain (USDA and NRCS, 2000; Wuana and Okieimen, 2011).



CHAPTER THREE

MATERIALS AND METHODS

3.1 STUDY AREA

Accra is the largest city in Ghana in terms of industrial establishment and infrastructural development. It is a coastal city and one of the major e-wastes dumping sites in West Africa (Otsuka *et al.*, 2011). The study was conducted at the Agbogbloshie scrap market in Accra.

Agbogbloshie is a suburb of Accra and covers approximately four acres. It is situated along the banks of the Korle Lagoon, northwest of Accra's Central Business District. The population of Agbogbloshie is about 40,000 inhabitants. This consists of economic migrants from northern and rural parts of Ghana, who for the quest of a better life have been compelled a move to urban settings. The inhabitants of Agbogbloshie live, eat, work and relieve themselves on the land and amongst the waste. Most of the structures there lack water and sanitation.

3.2 ACTIVITIES AT THE SITE

The economy at the Agbogbloshie scrap market is hinged on electronic waste imports and the processing of the goods. Most of the electronic waste imports come from the United States, although there are other arrivals from the United Kingdom, Germany, Switzerland and the Netherlands. Various brands of electronic products that are imported include Philips, canon, dell, Microsoft, Nokia, Siemens and Sony. Donations from Non-governmental organizations (NGO) also add up to the waste as excess electronics are given in the form of help to institutions. Estimated 50% to 75% of the electronics imported are unable to be salvaged and remain on the land. Also, due to an

uncertainty of how to manage electronic items about 75% of the items are stored (Ramachandra and Saira, 2004).

The workers, many of whom are boys and fall within the ages 11-20 years search for the metals copper, aluminium and iron to sell. The metal scraps are sold by workers, children and adults alike, to earn a living. The workers dismantle the electronic waste with their bare hands and stones and other rudimentary tools with no protective equipments (Brigden *et al.*, 2008).

In order to recover the metals, certain materials especially plastics are taken to the sites for processing (Ramachandra and Saira, 2004). The lagoons have extremely low levels of oxygen as a result of the large and uncontrolled quantities of domestic and industrial waste being discharged into the water. There the workers use old foam to burn on top of the electronics to melt the plastics. The use of the foam mainly from obsolete refrigerators (polyurethane) is to sustain and enhance the fire for the burning process. The open air burning brings along with it toxic fall-out which affects both the local environment and broader global air currents. By-products which are highly toxic deposit in many places (Ramachandra and Saira, 2004). Magnets are then used to gather the smallest of the metal scraps left behind in the process (Brigden *et al.*, 2008). Then the metals are now ready for sale.

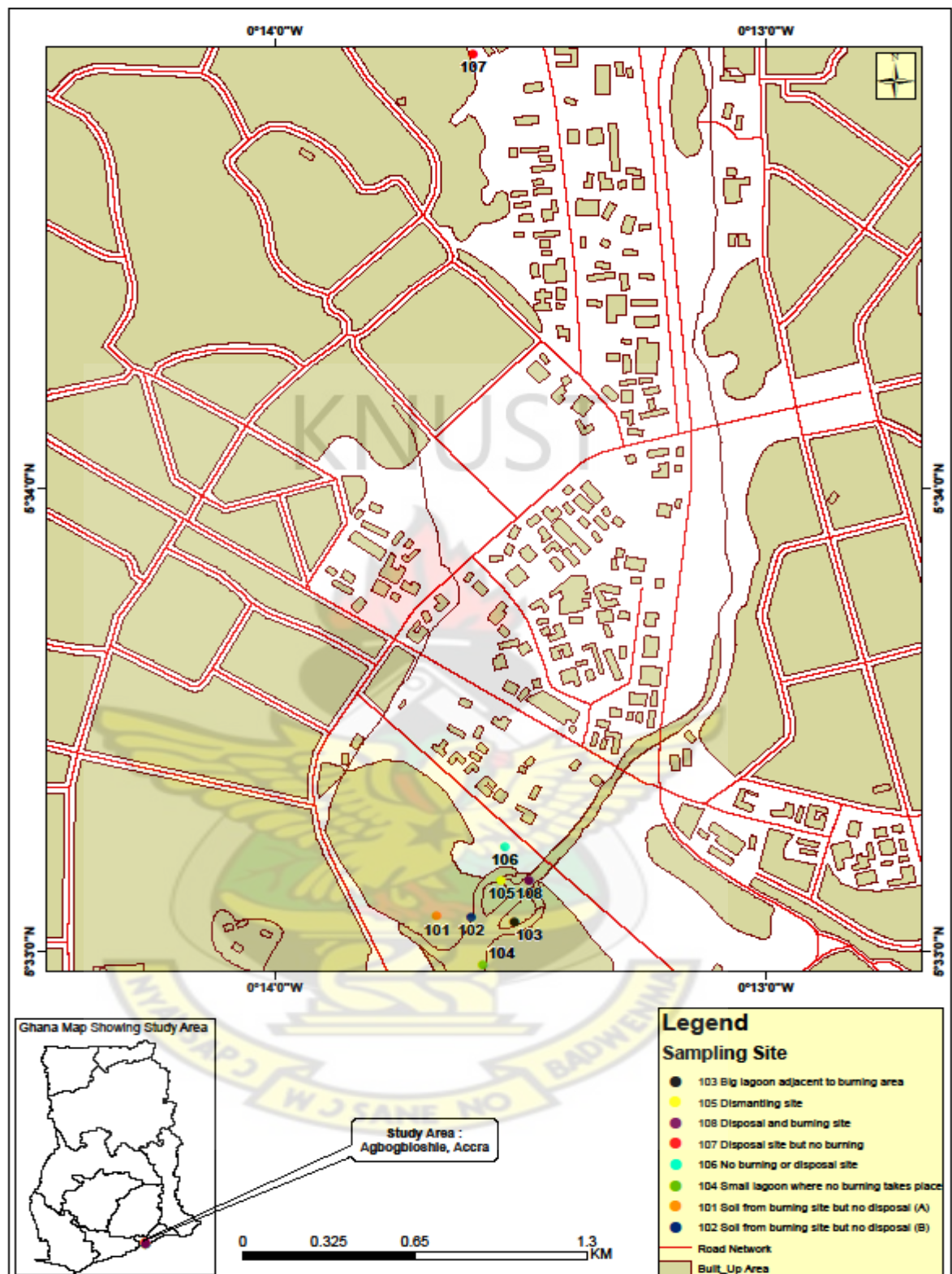


Figure 1: Map showing sampling sites at Agbogbloshie scrap market, Accra.

Table 1: Location and sampling code of samples (Degree, Decimal minutes)

SAMPLING SITE	LATITUDE	LONGITUDE
101	5° 33.077'N	0° 13.670'W
102	5° 33.076'N	0° 13.601'W
103	5° 33.065'N	0° 13.512'W
104	5° 32.972'N	0° 13.576'W
105	5° 33.155'N	0° 13.539'W
106	5° 33.228'N	0° 13.532'W
107	5° 34.938'N	0° 13.596'W
108	5° 33.154'N	0° 13.482'W

Table 2: Description of samples

SAMPLING SITES	SAMPLES	DESCRIPTION
101	S _A	Soil collected from burning site with no disposal.
102	S _B	Soil taken from location where burning takes place but no disposal.
103	W _b	Big lagoon adjacent to burning area.
104	W _s	Small lagoon where no burning takes place.
105	S _C	Soil collected within the dismantling area.
106	S _D	Soil collected at a location where neither burning nor disposal takes place.
107	S _E	Soil collected at a disposal site where no burning takes place.
108	S _F	Soil collected at a disposal site where burning takes place.

3.3 SAMPLE COLLECTION AND PREPARATION

3.4 SOIL SAMPLES

The soil samples from the various sampling sites shown in tables 1 and 2 and figure 1 were all taken at a depth of 0 to 15 cm each with the help of garden shovel cleaned with concentrated nitric acid. Three (3) samples were taken from each sampling site. The soil samples were collected into plastic containers which had all been pre-cleaned with concentrated nitric acid. The reason was to remove any traces of heavy metal contaminant (Brigden *et al.*, 2008). The collected soil samples were then transported to ECOLAB, Legon for further treatment.

3.5 WATER SAMPLES

The water samples (lagoon) were also collected into plastic voltic bottles that had been pre-cleaned with concentrated nitric acid and finally rinsed with distilled water. The bottles were rinsed again with water from the lagoon. The sampling sites are shown in tables 1 and 2 and figure 2. Three (3) samples were taken from each sampling site and in each concentrated nitric acid were added. They were kept in an ice chest with ice-cubes and then transported to ECOLAB, Legon. Upon arrival in the laboratory the water samples were moved into a fridge and then kept for further analysis.

3.6 METHOD USED

3.7 SOIL SAMPLES

The soil samples were air dried to constant weight and sieved using a 2 mm mesh (Brigden *et al.*, 2008). For each dried soil sample, 1 g was weighed into a boiling tube

which has been washed with concentrated nitric acid (HNO_3) and distilled water. Then 15 ml of a ternary mixture (20 ml conc. HClO_4 , 500 ml conc. HNO_3 and 50 ml conc. H_2SO_4) was added to each weighed soil sample in the boiling tube. The samples were then digested using a block digester under fume hood for 24 minutes. The solutions were allowed to cool, and then distilled water added to each and filtered into a 100 ml Pyrex volumetric flask using a Whatman No 42 filter, 9 cm. It was then made up to the mark with distilled water. The solutions were then stored for heavy metal determination using AAS (Perkin Elmer 400 Atomic Absorption Spectrophotometer).

3.8 WATER SAMPLES

The raw water samples were filtered using a Whatman No 42 filter, 9 cm. The pH of the water samples was determined using digital analyzer model 691 pH- Meter (Swiss Made) followed by the conductivity using conductometer E 587 (Swiss Made). Then 100 ml of the filtrate was measured into a beaker with the addition of 15 ml concentrated nitric acid solution and 10 ml of 50% concentrated hydrochloric acid solution (Wufem *et al.*, 2009). The content was evaporated to almost dryness on a hot plate, 7 ml of 50% concentrated hydrochloric acid added and heated for 10 minutes. The solutions were allowed to cool, and then distilled water added to each and filtered into a 100 ml Pyrex volumetric flask using a Whatman No 42 filter, 9 cm. This was then made up to the mark with distilled water. The 100 ml each of the water samples was used for the heavy metal determination using AAS (Perkin Elmer 400 Atomic Absorption Spectrophotometer).

Both methods were used to determine some selected heavy metals in both the soil and the water samples.

CHAPTER FOUR

4.0 RESULTS

4.1 HEAVY METALS IN SOIL SAMPLES

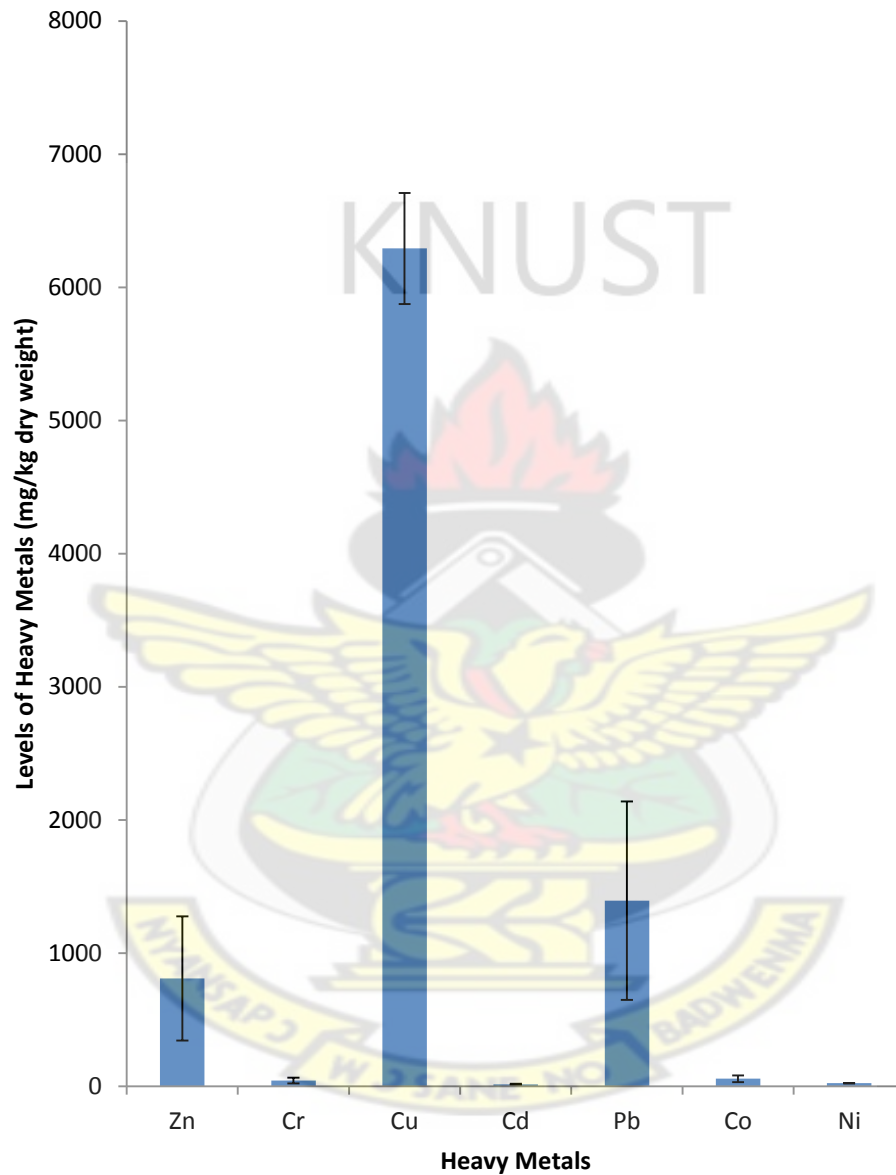


Figure 2: The mean concentration of heavy metals in soil sample S_A (mg/kg dry weight).

The mean concentration of heavy metals in soil sample S_A ranged from 13.8 to 6291.33 mg/kg dry weight (Figure 2). The concentration of Cu was the highest among

the heavy metals studied (6291.33 mg/kg dry weight) whiles Cd was the lowest with 13.8 mg/kg dry weight. The concentrations of Zn, Cu, Cd and Pb in soil sample S_A exceeded the Dutch intervention values of 720, 190, 12 and 530 mg/kg dry weight. Only Co had its value exceeding the Dutch target value of 20 mg/kg dry weight but below the Dutch intervention value of 240 mg/kg dry weight (Figure 2). However, the concentrations of both Cr and Ni were below their respective Dutch target and intervention values.

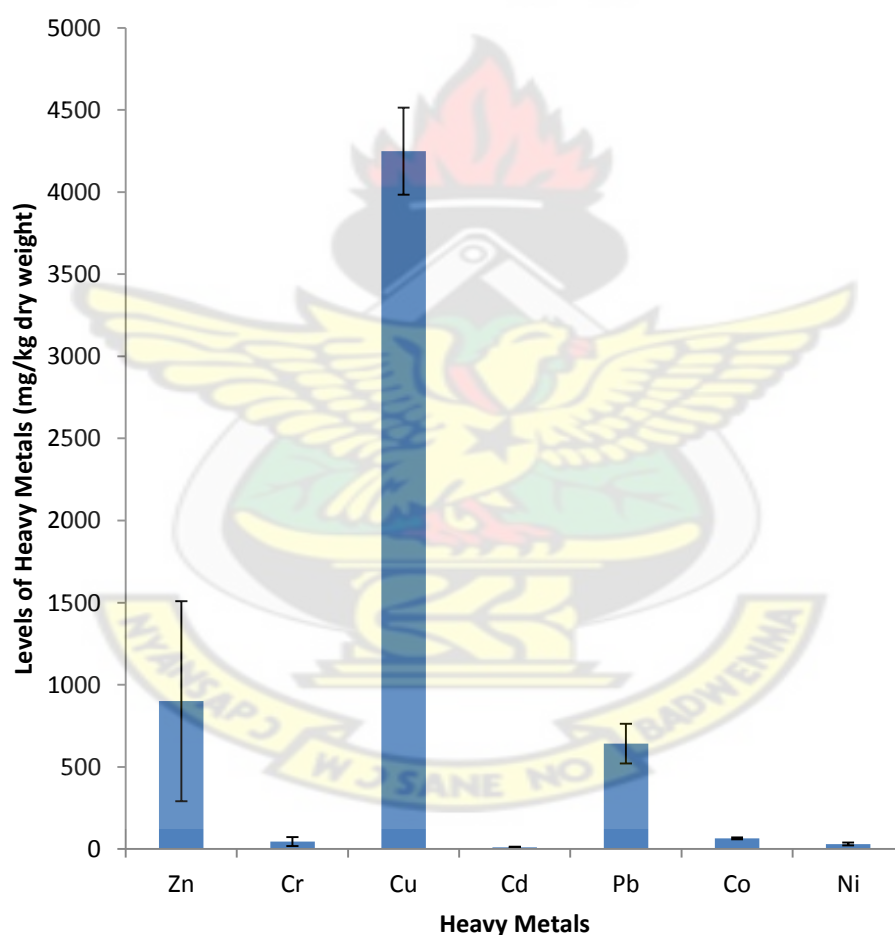


Figure 3: The mean concentration of heavy metals in soil sample S_B (mg/kg dry weight).

The maximum concentration for the heavy metals was Cu (4249.33 mg/kg dry weight) and the minimum value being Cd (10.73 mg/kg dry weight). The heavy metals in soil sample S_B had its mean concentration ranging from 10.73 to 4249.33 mg/kg dry weight (Figure 3). Also the concentrations of Zn, Cu, and Pb in soil sample S_B exceeded the Dutch intervention values of 720, 190, and 530 mg/kg dry weight. The mean concentrations of Cd and Co exceeded the Dutch target values of 0.8 and 20 mg/kg dry weight but below the Dutch intervention values of 12 and 240 mg/kg dry weight respectively (Figure 3). Also the concentrations of Cr and Ni did not exceed both their respective Dutch target and intervention values.

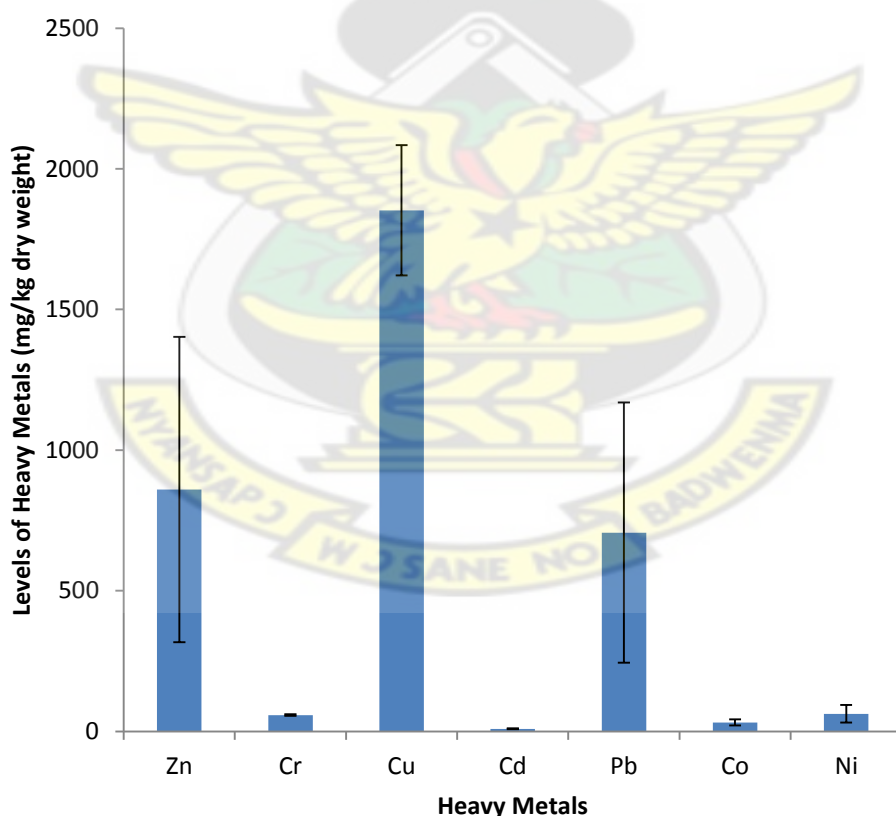


Figure 4: The mean concentration of heavy metals in soil sample S_C (mg/kg dry weight).

The mean concentration of Zn, Cu and Pb in soil sample S_C exceeded the Dutch intervention values of 720, 190 and 530 mg/kg dry weight respectively. Also Cd, Co and Ni had their mean concentrations above the Dutch target values of 0.8, 20 and 35 mg/kg dry weight but below the Dutch Intervention values of 12, 240 and 210 mg/kg dry weight respectively (Figure 4). Only Cr had its concentration below both the Dutch target and intervention values. The mean concentrations obtained for heavy metals in soil sample S_C ranged from 9.13 to 1852.33 mg/kg dry weight (Figure 4). The highest concentration being copper was 1852.33 mg/kg dry weight while the lowest value was Cd (9.13 mg/kg dry weight).

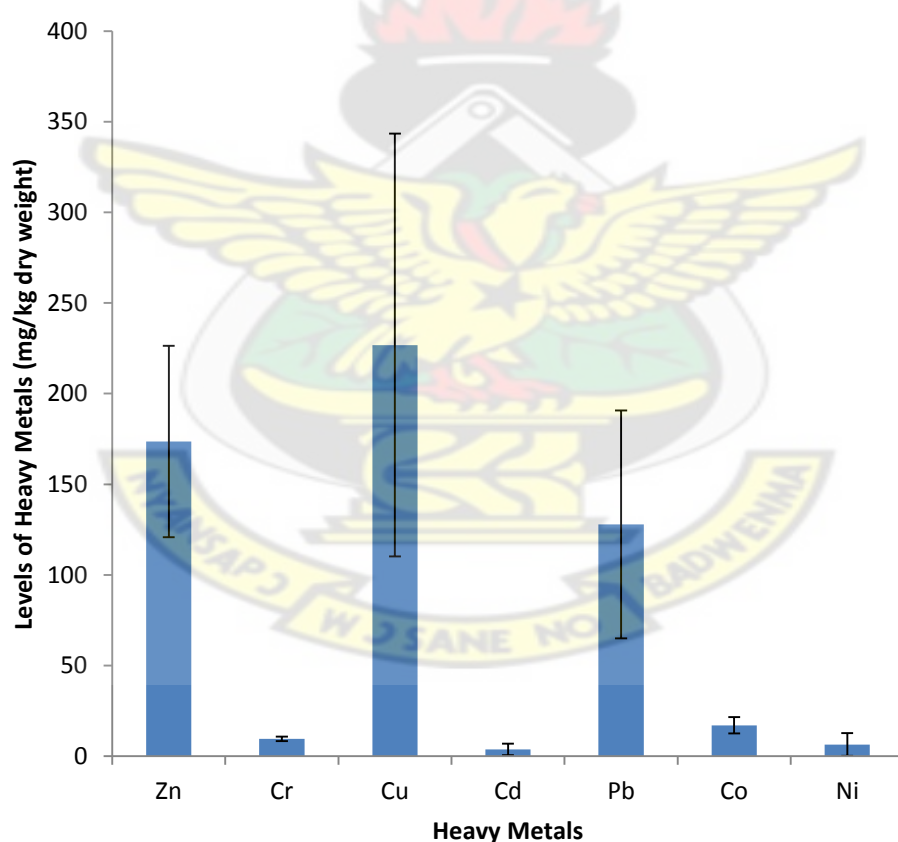


Figure 5: The mean concentration of heavy metals in soil sample S_D (mg/kg dry weight).

Only Cu in soil sample S_D had its mean concentration value exceeding the Dutch intervention value of 190 mg/kg dry weight. It also had the highest value (226.80 mg/kg dry weight) while the lowest value was Cd (3.70 mg/kg dry weight). The mean concentration range for the heavy metals in soil sample S_D was from 3.70 to 226.80 mg/kg dry weight (Figure 5). The concentrations of Zn, Cd and Pb were above the Dutch target values of 140, 0.8 and 85 mg/kg dry weight but below the Dutch intervention values of 720, 12 and 530 mg/kg dry weight respectively (Figure 5). However, Cr, Co and Ni concentrations did not exceed both the Dutch target and intervention values.

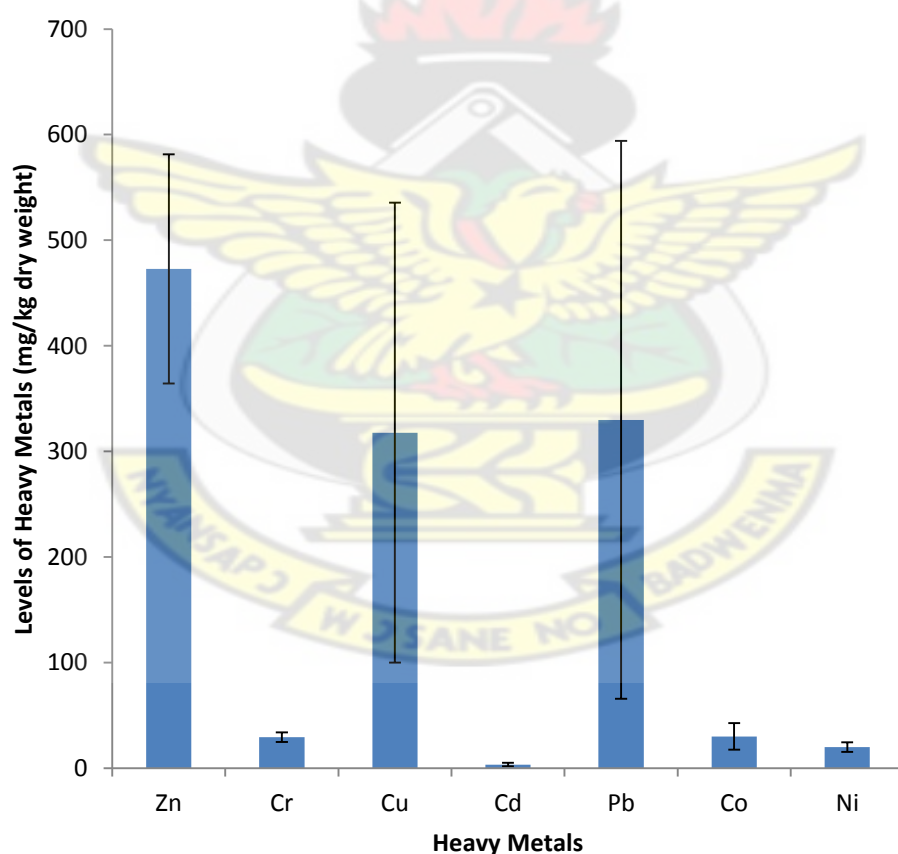


Figure 6: The mean concentration of heavy metals in soil sample S_E (mg/kg dry weight).

The highest concentration was Zn (472.87 mg/kg dry weight) while the lowest was Cd (3.47 mg/kg dry weight). The heavy metal concentrations in soil sample S_E ranged from 3.47 to 472.87 mg/kg dry weight (Figure 6). Only Cu in soil sample S_E exceeded the Dutch intervention value of 190 mg/kg dry weight. Then Zn, Cd, Pb and Co mean concentration values were above the Dutch target values of 140, 0.8, 85 and 20 mg/kg dry weight but below the Dutch intervention values of 720, 12, 530 and 240 mg/kg dry weight respectively (Figure 6). However, Cr and Ni concentrations were very low.

The concentrations of Cr and Ni did not exceed both the Dutch target and intervention values. Cu was the only heavy metal in soil sample S_F to have exceeded the Dutch intervention value of 190 mg/kg dry weight. The mean concentration in soil sample S_F also ranged from 5.13 to 1458.47 mg/kg dry weight (Figure 7). Cu was the highest (1458.47 mg/kg dry weight) and the lowest was Cd (5.13 mg/kg dry weight). Then also Zn, Cd, Pb and Co concentrations exceeded the Dutch target values of 140, 0.8, 85 and 20 mg/kg dry weight but not the Dutch intervention values of 720, 12, 530 and 240 mg/kg dry weight respectively (Figure 7).

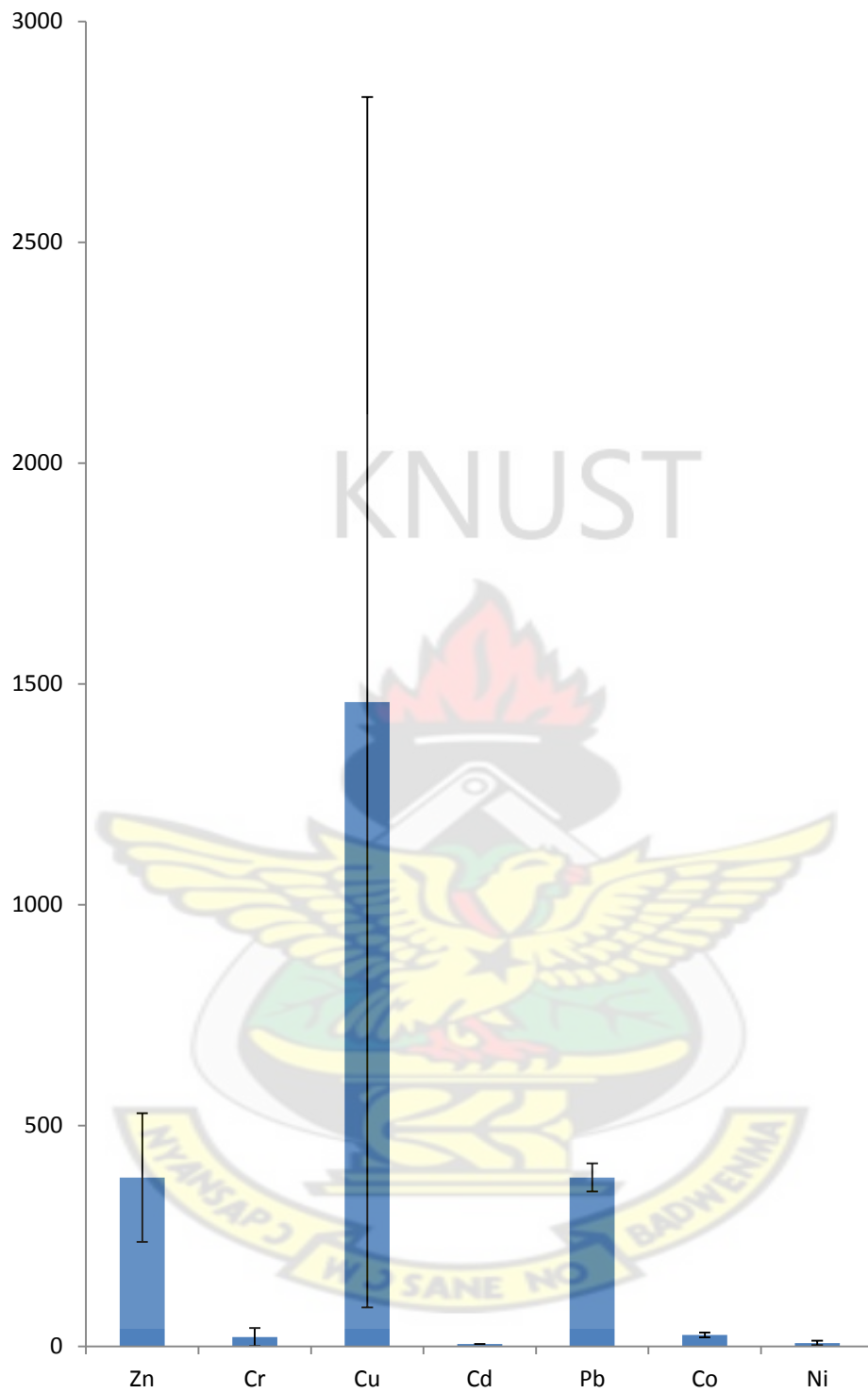


Figure 7: The mean concentration of heavy metals in soil sample S_F (mg/kg dry weight).

4.2 HEAVY METALS IN WATER SAMPLES

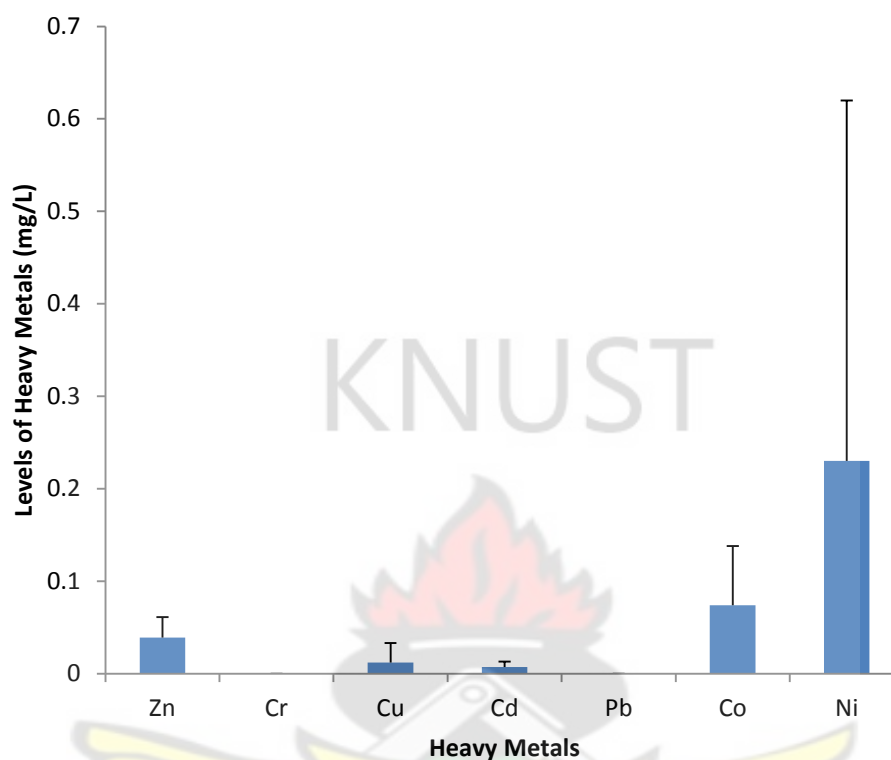


Figure 8: The mean concentration of heavy metals in water sample W_b (mg/L).

The mean concentrations for the heavy metals in the water sample W_b ranged from 0 to 0.23 mg/L (Figure 8). The 0 mg/L here means that the levels were below detection limit. Ni was the highest with 0.23 mg/L, and the lowest being that of Cr and Pb (0 mg/L). Cd and Ni in water sample W_b were above the Dutch intervention values of 0.006 and 0.075 mg/L respectively. Also Co had its mean concentration exceeding the Dutch target value of 0.02 but below the Dutch intervention value of 0.1 mg/L respectively (Figure 8). But Zn, Cr, Cu and Pb concentrations were below both the Dutch target and intervention values.

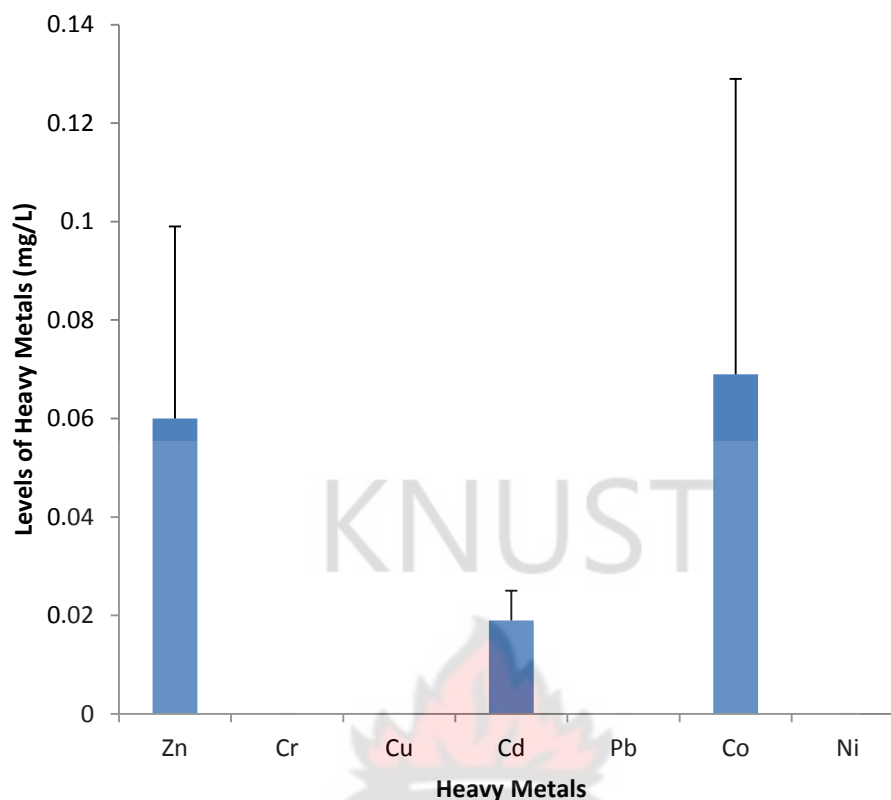


Figure 9: The mean concentration of heavy metals in water sample W_s (mg/L).

Zn, Cr, Cu, Pb and Ni did not exceed both the Dutch target and intervention values. Co was the highest (0.069 mg/L) and the lowest being that of Cr, Cu and Pb (0 mg/L). Also the concentration of Co exceeded the Dutch target value of 0.02 mg/L. The 0 mg/L again means that the levels were below detection limit. The mean concentration values for heavy metals in water sample W_s ranged from 0 to 0.069 mg/L (Figure 9). Only the concentration of Cd in the water sample W_s exceeded the Dutch intervention value of 0.006 (Figure 9).

CHAPTER FIVE

DISCUSSION

5.1 HEAVY METALS IN SOILS

The levels of heavy metal concentrations measured in the various soil samples together with

some soil quality standards using the new Dutch list are shown in table 5 (appendix) and figures 2 to 7.

Among the soil samples tested copper (Cu), lead (Pb), zinc (Zn) and cadmium (Cd) were the most abundant in the soil samples with 6291.92 mg/kg, 1392.67 mg/kg, 899.90 mg/kg and 13.80 mg/kg respectively. This was in line with the study carried out by Leung *et al.* (2006) which recorded Cu (712 mg/kg), Pb (316 mg/kg) and Zn (258 mg/kg) as the most abundant metals among the environmental samples considered. The varying concentration levels of the heavy metals were due to the differences in location and sampling sites.

Zn concentrations in soil samples S_A, S_B and S_C of 810.53 mg/kg, 899.90 mg/kg and 860.17 mg/kg respectively exceeded the new Dutch list intervention value of 720 mg/kg (Table 5). In comparison to Zn levels reported by Leung *et al.* (2006), the concentrations recorded for this study were higher because of the differences in the sampling sites and the method used in recycling the metal. The sampling site 102 contained the highest level of Zn among the sites studied. The increased levels of zinc (Zn) at the sites could be attributed to the burning of the electronic waste and the dismantling activities to recover various metals. High levels of Zn can also influence the activity of microorganisms and earthworms thereby retarding the breakdown of organic matter (Wuana and Okieimen, 2011).

In the case of copper (Cu) the concentrations in all the soil samples exceeded the new Dutch list intervention value of 190 mg/kg (Table 5). Generally, the levels of Cu obtained from this study were higher than the one reported by Leung *et al.* (2006). The intensive nature of Cu recovery using different electronic product parts and the sampling sites could have accounted for this trend. With all the sampling sites studied site 101 was highly contaminated. The level of Cu in this site was 6291.33 mg/kg. This was 33 times the Dutch Intervention value of 190 mg/kg. The copper (Cu) levels may have been due to the intensive dismantling and burning activities to recover the metal. Air deposition and runoff could also be a factor. This accounted for why the copper (Cu) concentration in soil sample S_D (226.80 mg/kg) exceeded the new Dutch list intervention value of 190 mg/kg. The high levels of copper (Cu) determined was as a result of the fact that it does not travel very far after being released. This limited mobility explains why copper (Cu) accumulate in soils (Adelekan and Abegunde, 2011). In high doses copper (Cu) may result in anaemia, liver and kidney damage, and stomach and intestinal irritation (Lenntech, 2010; Wuana and Okieiman, 2011).

Only the concentration of cadmium (Cd) in soil sample S_A of 13.80 mg/kg exceeded the new Dutch list intervention value of 12 mg/kg (Table 5). The levels of Cd even though low were still higher than the levels reported by Leung *et al.* (2006). This may have been due to the intensive nature of the dismantling at the study site. The level of the cadmium (Cd) in the soil may have come from the burning of the plastics to recover the metals and also from the Ni/Cd batteries dumped in the area (Hardy *et al.*, 2008). Generally, the low levels of Cd obtained compared to the other heavy metals in the soils could be attributed to the high mobility of Cd through the soil layers. Cd is likely to be more mobile in soil systems than many other heavy metals (Adelekan and Abegunde, 2011). High levels of cadmium (Cd) exposure may lead to severe pains in

the joints, bone diseases, kidney and lung problems and anaemia (Hardy *et al.*, 2008). It may affect sperm, reduces birth weight and a causal factor in cardiovascular diseases and hypertension (Adelekan and Abegunde, 2011; Asio, 2009). Also Cd exposure can lead to situations such as neurotoxin, hypertension, carcinogenic, teratogenic, liver dysfunction, nausea, vomiting, respiratory difficulties, cramps and loss of consciousness (Adelekan and Abegunde, 2011; Bhagure and Mirgane, 2010).

The high level of the lead in the soils may have come from the storage batteries and the cable covers burnt to recover the copper. Lead (Pb) concentrations in soil samples S_A, S_B and S_C of 1392.67 mg/kg, 642.27 mg/kg and 706.60 mg/kg respectively also exceeded the new Dutch list intervention value of 530 mg/kg (Table 5). The Pb concentrations recorded from this study were generally higher than the Pb concentrations reported by Leung *et al.* (2006). This could also be due to the differences in the electronic product part recycled, the intensive nature of the activities and the method used. The increased levels of lead (Pb) could potentially become toxic to microorganisms. It can lead to decreased litter decomposition and nitrogen fixation, less efficient nutrient cycling and impaired enzyme synthesis (Adelekan and Abegunde, 2011). Lead (Pb) exposure can result in weakness of the joints, failures of reproduction, nausea and loss of memory (Asio, 2009).

The rest of the other metals did not exceed the Dutch intervention level. But Zn, Cu, Cd, Pb and Co concentrations for soil samples S_A, S_B, S_C, S_E and S_F exceeded the respective Dutch target values.

The significant levels of cobalt (Co) in the various soil samples may have come from the various magnetic steels and stainless steels dumped in the area. High level exposure can also result in bronchial asthma, interstitial lung disease and lung cancer (Kim *et al.*, 2006).

It was also noted that only Ni concentration (62.53 mg/kg) of soil sample S_C exceeded the Dutch target value of 35 mg/kg (Table 5). Ni levels obtained from this study were lower than the one reported by Leung *et al.* (2006). It could have been due to the varying activities at the site and differences in the sampling sites. The activities include dismantling and the Ni/Cd batteries dumped in the area (Hardy *et al.*, 2008). However, long term exposure can cause decreased body weight, heart and liver damage, and skin irritation (Lenntech, 2010).

The concentrations of chromium in all the soil samples were low. Chromium (Cr) concentrations were all within the baseline concentrations for soils. It is non-biodegradable and as a result become persistent in the environment. The decreased concentrations determined in the various soil samples could be due to its transformation into various mobile forms before ending into the environmental sink (Adelekan and Abegunde, 2011). But low-level exposure can irritate the skin and cause ulceration while long-term exposure can cause damage to the kidney and liver as well as damage to circulatory and nerve tissues (Lenntech, 2010).

It can be deduced that soil sample S_D was contaminated with copper (Cu) in terms of the heavy metals studied. The same was observed for soil samples S_E and S_F concerning the heavy metals studied.

But in the case of soil sample S_A there was high level contaminations by Zn, Cu, Cd and Pb. Also the soil sample S_B was highly contaminated with Zn, Cu and Pb of the heavy metals studied. In low concentrations Cu, Ni and Zn are essential to plants and animals by serving as components of enzymes, structural proteins and pigments. They also help to maintain ionic balance of cells (Adelekan and Abegunde, 2011). Then for soil sample S_C the heavy metals of concern were also the same as that of soil sample S_B.

Therefore the heavy metals measured in the various soil samples can be arranged as follows,

starting from the highest to the lowest in terms of contamination.

Soil sample S_A : $Cu > Pb > Zn > Co > Cr > Ni > Cd$

Soil sample S_B : $Cu > Zn > Pb > Co > Cr > Ni > Cd$

Soil sample S_C : $Cu > Zn > Pb > Ni > Cr > Co > Cd$

Soil sample S_D : $Cu > Zn > Pb > Co > Cr > Ni > Cd$

Soil sample S_E : $Zn > Pb > Cu > Co > Cr > Ni > Cd$

Soil sample S_F : $Cu > Pb > Zn > Co > Cr > Ni > Cd$

Then finally the arrangement can be deduced as follows;

$Cu > Pb > Zn > Co > Cr > Ni > Cd$

The sites 101, 102 and 105 were the most contaminated (Table 2). The burning sites and the dismantling site had high levels of Cu, Pb and Zn. However, the burning site 101 contained a high level of Cd. This meaning that burning and dismantling activities release a lot of heavy metals in the soil environment.

5.2 HEAVY METALS IN WATERS

The mean concentrations of heavy metals in the water samples are shown in table 8 (appendix) and figures 8 and 9 with their water standards using the new Dutch list.

The mean zinc (Zn) concentrations in the water samples W_S and W_B did not both exceed the Dutch target value of 0.065 mg/L and Dutch intervention value of 0.8 mg/L (Table 8). The presence of the zinc (Zn) may have come from wastewater from industrial plants and runoffs from the burning area.

However, there was no detection for the levels of both chromium (Cr) and lead (Pb).

This was as a result of binding characteristics and that the heavy metals concerned

were sequestered at the bottom of the water. It was observed in the work done by Brigden *et al.* (2008) that the sediments from the “korle” lagoon had both Cr and Pb concentrations of 34 mg/kg and 1685 mg/kg respectively. Aderinola *et al.* (2009) also confirmed that sediments were very important host for toxic metals. They allow for the detection of heavy metals that may be either absent or in low concentration in the water column.

But in the case of copper (Cu) the concentration of 0.012 mg/L was an indicative of contamination. This could have come from the burning to recover copper near the lagoon and also runoff. There was no detection for copper (Cu) in the water sample W_s. This can be due to the fact that in water copper (Cu) travel great distances either suspended on dust particles or as free ions (Adelekan and Abegunde, 2011). It was supported by the work by Brigden *et al.* (2008) which obtained Cu as 2260 mg/kg from the sediments. There was no burning activity near this site.

Cadmium (Cd) concentrations in both water samples exceeded the Dutch target value and Dutch intervention values of 0.0004 mg/L and 0.006 mg/L respectively (Table 8). These indicating heavy metals of major concern. The higher levels of the cadmium (Cd) may be attributed to large use of PVC plastics and Ni/Cd batteries. High Cd levels can have adverse effect on aquatic life and water quality (Bhagure and Mirgane, 2010).

Also, the concentrations of cobalt (Co) in both water samples exceeded the Dutch target value

of 0.02 mg/L but not the Dutch intervention value of 0.1 mg/L. They were therefore contaminated with cobalt (Co). This could have come from the magnetic steels and in batteries dumped in the area. Higher concentrations of cobalt become toxic to aquatic animals and plants and affects water quality (Bhagure and Mirgane, 2010).

No nickel (Ni) was detected in the water sample W_S . The concentration in the water sample W_B of 0.23 mg/L exceeded the Dutch target value of 0.015mg/L and Dutch intervention value of 0.075 mg/L (Table 8). The nickel in the water could have come from biological cycles and solubilization of its compounds from soil or sedimentation of nickel (Ni) from the atmosphere (Adelekan and Abegunde, 2011).

In the water sample W_B the heavy metals of major concern were copper (Cu), cadmium (Cd), cobalt (Co) and nickel (Ni).

Then for water sample W_S the heavy metals of major concern were also cadmium (Cd) and cobalt (Co) and zinc (Zn).



CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

Most components of electronic equipments are made up of heavy metals. The crude way of recycling them releases much more of the heavy metals into both the soil and the water environment. The presence of the heavy metals above the natural levels in the study area can also be attributed to other sources such as atmospheric deposition, industrial waste water discharges, transport sectors, sewage wastewater, etc. The intensive nature of dismantling and burning to recover the metals adds a lot to the increasing levels of the heavy metals present in the study area. Soil samples S_A , S_B and S_C had zinc (Zn), copper (Cu) and lead (Pb) all exceeding their Dutch intervention values of 720 mg/kg, 190 mg/kg and 530 mg/kg respectively. Copper (Cu) concentrations in all the samples exceeded the Dutch intervention value of 190 mg/kg. This gave credence to the crave for copper in the recycling activities at the study area. Cadmium (Cd) concentration in the soil sample S_A was also above the Dutch intervention value of 12 mg/kg. Then in the water samples the nickel (Ni) concentration in W_B exceeded the Dutch intervention value of 0.075 mg/L. But in the case of water samples W_B and W_S the cadmium (Cd) concentrations exceeded the Dutch intervention values of 0.006 mg/L. Cobalt (Co) concentration exceeded the Dutch target value of 0.02 mg/L in both the water samples W_B and W_S . Copper (Cu) concentration in the water sample W_B only exceeded the Dutch target value of 0.015 mg/L. Therefore the crude way of recycling electronic waste contributes to heavy metal contamination of both soil and water.

6.2 RECOMMENDATIONS

It is recommended that further research should look into the following;

1. Health screening should be carried out periodically on the workers and inhabitants to check for some symptoms of heavy metals inhalation.
2. Concentration of other heavy metals in the soils and as well as the “Korle” lagoons should be constantly monitored.
3. Water sediments from the “Korle” lagoon should be analysed for heavy metals.



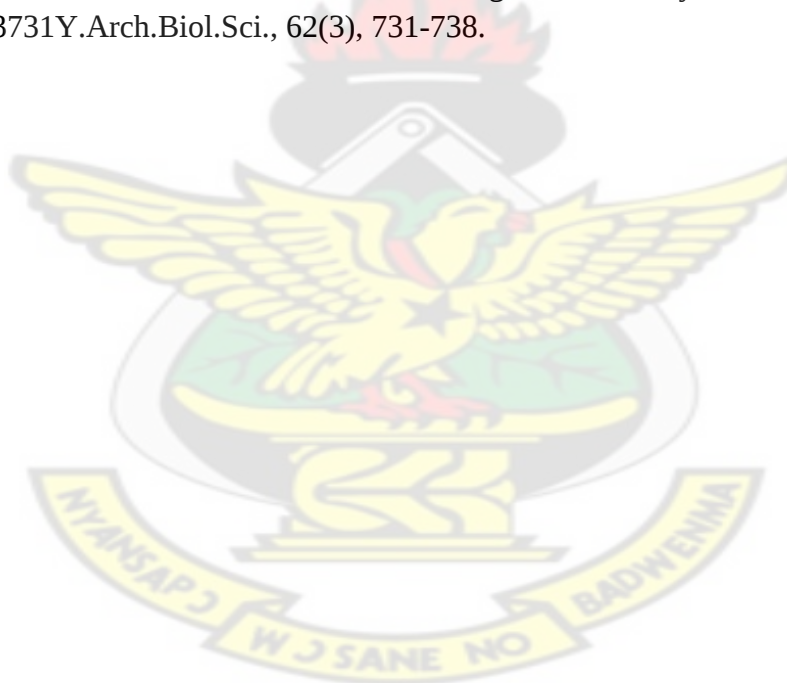
REFERENCES

- Adelekan B. A. and Abegunde K. D. (2011). Heavy Metals Contamination of Soil and Groundwater at Automobile Mechanic Villages in Ibadan, Nigeria. *International Journal of the Physical Sciences* vol. 6(5), pp. 1045-1058.
- Aderinola O. J., Clarke E. O., Olarinmoye O. M., Kusemiju V. and Anatekhai M. A. (2009). Heavy Metals in Surface Water, Sediments, Fish and Perwinkles of Lagos, Lagoon. *American-Eurasian J. Agric. & Environ. Sci.*, 5(5), pp. 609-617.
- Asio V.B. (2009). Heavy metals in the Environment and their Health effects. *Soil and Environment*, pp.1-5.
- Azimi, A. A., Navab Daneshmand, T. and Pardakhti, A., (2006). Cadmium Absorption and accumulation in different parts of Kidney beans, Radishes and Pumpkins. *Int. J. Environ. Sci.Tech.*, 3 (2), 177-180.
- Bhagure G. R. and Mirgane S. R. (2010). Heavy Metals Contaminations in groundwater and soils of Thane Region of Maharashtra, India, *Environ Monit Assess* pp. 1-10.
- Brigden K., Labunska I., Santillo D. and Johnson P. (2008). Chemical Contamination at E-waste Recycling and Disposal Sites in Accra and Koforidua, Ghana. *Greenpeace Research Laboratories Technical Note*, pp.1-23.
- Dávila O. G., Gómez-Bernal J. M. and Ruiz-Huerta E. A. (2012). Plants and soil Contamination with Heavy Metals in Agricultural areas of Guadalupe, Zacatecas, Mexico, *Environmental Contamination*, Dr. Jatin Srivastava (Ed.), ISBN: 978-953-51- 0120-8, InTech, Available from: <http://www.intechopen.com/books/environmental-contamination/plants-and-soil-contamination-with-heavy-metals-in-agricultural-areas-of-guadalupe-zacatecas-mexico> pp. 37-50.
- Doherty V.F., Kanife U.C., Ladipo M.K. and Akinfemi A. (2011). Heavy Metal Levels in Vegetable from selected Markets in Lagos, Nigeria. *Electronic Journal of Environmental, Agricultural and Food Chemistry (EJEAFCh)*, 10(2):1887-1891.

- Dutch Standards. [http://esdat.net/ Environmental Standards.aspx](http://esdat.net/EnvironmentalStandards.aspx) (Accessed on 4th September, 2012).
- Dutch Standards. [http://www.ere.com.my/downloads/Soil-Dutch List.pdf](http://www.ere.com.my/downloads/Soil-DutchList.pdf) (Accessed on 4th September, 2012).
- El Boouraie M. M., El Barbary A. A., Yeyia M. M. and Motawea E. A. (2010). Heavy Metal Concentrations in Surface River Water and bed Sediments at Nile Delta in Egypt, Finnish Peatland Society, ISSN 0039-5471, Suo 61(1), pp. 1-12.
- Ene A., Boşneagă A. and Georgescu L. (2009). Determination of Heavy Metals in Soils using XRF Technique, University of Galati, Faculty of Sciences, Chemistry Department, 111 Domneasca St, 800201 Galati, Romania pp. 815-820.
- Friedlova M. (2010). The Influence of Heavy Metals on Soil Biological and Chemical Properties. Soil and Water Res., S, (1): 21-27.
- Hardy D. H., Myers J. and Stokes C. (2008). Heavy Metals in North Carolina Soils Occurrence & Significance. N.C. Department of Agriculture and Consumer Services, pp. 1-2.
- Harikumar P. S., Prajitha K. and Silpa S. (2010). Assessment of Heavy Metal Contamination in the Sediments of a River Draining into a Ramsar Site in the Indian Sub Continent. J.Adv.Lab. Res.Bio (www.jalrb.com).Vol.1 Issue II. Pp.157-169.
- Jung M. C. (2001). Heavy Metal Contamination of Soils and Waters in and around the Imecheon Au-Ag mine, Korea. Applied Geochemistry, vol. 16, pp. 1369-1375.
- Kim J. H., Gibb H. J. and Howe P. D. (2006). Cobalt and inorganic cobalt compounds, WHO, International Chemical Assessment Document 69, pp. 1-85.
- Lenntech (2010). Heavy Metals. www.lenntech.com. Accessed on 2nd July, 2012. pp.1-3.
- Lenntech (2012). Chemical Properties of Cobalt, Health Effects of Cobalt and Environmental Effects of cobalt. [www. Lenntech.com](http://www.Lenntech.com). Accessed on 3rd July, 2012. pp.15.
- Leung A., CAI Z.W. and Wong M.H. (2006). Environmental Contamination from Electronic Waste Recycling at Guiyu, southeast China. J.Mater Cycles waste Manag, 8:21-33.
- Makino T., Luo Y., Wu L., Sakurai Y., Maejima Y., Akahane I and Arao T. (2010). Heavy Metal Pollution of Soil and Risk Alleviation Methods Based on Soil Chemistry, pedologist. pp.38-49.
- Nassef M., Hannigan R., EL Sayed K. A. and Tahawy M. S. EL. (2006). Determination of some Heavy Metals in the Environment of Sadat Industrial City, 2nd Environmental Physics Conference, 18-22nd Feb. pp. 145-152.

- Obodai E.A., Boamponsem L.K., Adokoh C.K., Essumang D.K., Villawoe B.O., Aheto D.W. and Debrah J.S. (2011). Concentration of Heavy Metals in two Ghanaian Lagoons. *Archive of Applied Science research*.3(3) : 177-187.
- Oluyemi E. A., Adekunle A. S., Adenuga A. A. and Makinde W. O. (2010). Physico-chemical Properties and Heavy Metal content of Water Sources in Ife North Local Government Area of Osun State, Nigeria. *African Journal of Environmental Science and Technology* Vol.4 (10), pp. 691-697.
- Otsuka M., Itai T., Asante K. A., Muto M. and Tanabe S. (2011). Trace Element Contamination around the E-waste Recycling Site at Agbogbloshie, Accra City, Ghana. Center for Marine Environmental Studies (CMES), Ehime University, Bunkyo-cho 2-5, Matsuyama 790-8577, Japan. pp. 161-167.
- Rajaganapathy V., Xavier F., Sreekumar D. and Mandal P. K. (2011). Heavy Metal Contamination in Soil, Water and Fodder and their presence in Livestock and Products: A Review. *Journal of Environmental Science and Technology*, 4:234-249.
- Ramachandra T.V. and Saira V. K. (2004). Environmentally Sound Options for E-wastes Management. *Envis Journal of Human Settlements*, pp. 1-11.
- Şerban A. S. (2000). Surface Water Pollution with Heavy Metals in the Lower Catchment of Jiu River Basin, according to the Water Framework Directive, *aerapa.Conference. Ubbcluj.rc*. pp. 357-364.
- Shayley H., McBride M, and Harrison E. (2009). Sources and Impacts of Contaminants in Soils. *Cornell Waste Management Institute*. pp.1-6.
- Stavrianou W. (2007). The Western Australian Contaminated Sites Act 2003: The Applicability of Risk Assessment as a basis for the Assessment and Management of Site Contamination, *www.awu.edu.au* pp. 1-92.
- Suciu I., Cosma C., Todica M., Bolboaca S.D. and Jantschi L. (2008). Analysis of Soil Heavy Metal Pollution and Pattern in Central Transylvania. *International Journal of Molecular Sciences*, 9(4) : 434-453.
- USDA and NRSC (2000). Heavy Metal Soil Contamination. *Soil Quality-Urban Technical Note.No.3*. pp.1-7.
- Varalakshmi L. R. and Ganeshamurthy A. N. (2010). Heavy Metal Contamination of Water Bodies, Soils and Vegetables in peri urban areas of Bangalore City of India, Division of Soil Science & Agricultural Chemistry, Indian Institute of Horticultural Research, Hessaraghatta Lake Post, Bangalore-560 089, Karnataka, India, Email lakkireddy7@yahoo.co.in pp. 37-40.
- Wäjer P.A, Hischer R. and Eugster M. (2011). Environmental impacts of the Swiss collection and recovery systems for waste Electrical and Electronic Equipment (WEEE): A follow-up. *Science of the Total Environment* 409, pp. 1746-1756.
- Warmate A.G., Ideriah T.J.K., Tamunobereton A.R.I., Udonam Inyang U.E. and Ibaraye T. (2011). Concentration of Heavy Metals in Soil and Water Receiving used Engine oil in Port Harcourt, Nigeria. *Journal of Ecology and the Natural Environment* Vol.3 (2), pp.54-57.

- Wei B. and Yang L. (2010). A review of Heavy Metal Contamination in Urban Soils, Urban Road Dust and Agricultural Soils from China. *Microchemical Journal*, 94, pp.99-107.
- Worksafe V. (2005). *Industry Standard Contaminated Construction Sites*. EPA Victoria, www.worksafe.vic.gov.au, First Edition. pp. 1-28.
- Wuana R. A. and Okieimen F. E. (2011). Heavy Metals in Contaminated Soils: A Review of Sources, Chemistry, Risks and Best Available Strategies for Remediation, *ISRN Ecology*, vol. 2011, Article ID 402647, 20 pages, doi:10.5402/2011/402647.
- Wufem B.M., Ibrahim A.Q., Gin N.S., Shibdawa M.A., Adamu H.M. and Agya P.J. (2009). Levels of Heavy Metals in Gubi Dam Water Bauchi, Nigeria. *Global Journal of Environmental Sciences* Vol.8, No.2, pp.29-37.
- Yahaya A., Adegbe A. A. and Emurotu J. E. (2012). Assessment of Heavy Metal content in the Surface Water of Oke-Afa Canal Isolo Lagos, Nigeria. *Archives of Applied Science Research*, 4(6), pp. 2322-2326.
- Yildiz D., Kula I., AY G., Baslar S. and Dogan Y. (2010). Determination of Trace Elements in the Plants of Mt.Bozdag, Izmir,Turkey. DOI:10.2298/ABS1003731Y. *Arch.Biol.Sci.*, 62(3), 731-738.



APPENDICES

APPENDIX A

Table 3: Heavy metal concentrations of soil samples collected from Agbogbloshie scrap market (mg/kg dry weight), first samples.

Soil Samples	Zn	Cr	Cu	Cd	Pb	Co	Ni
S _A (1)	1349	67.4	6743	8.6	532	26.2	21.1
S _B (1)	1602	75.9	3943	7.2	503	57.3	20.8
S _C (1)	1487	54.5	1585	7.7	172.8	19.5	26.7
S _D (1)	112.7	8.2	92.1	7.4	55.3	22.2	13.7
S _E (1)	347.7	24.3	66.2	5.3	25	15.6	14.7
S _F (1)	214.1	44.6	3041	5	419	19.2	13.5

Table 4: Heavy metal concentrations of soil samples collected from Agbogbloshie scrap market (mg/kg dry weight), second samples.

Soil Samples	Zn	Cr	Cu	Cd	Pb	Co	Ni
S _A (2)	541.4	29.2	6212	16.4	1826	71	23.3
S _B (2)	548.8	29.4	4403	12.4	711.9	68	35.4
S _C (2)	546.7	59.3	1986	9.8	973.5	37.7	80.4
S _D (2)	204.1	10.4	294.2	1.9	164.2	14.4	2.9
S _E (2)	532.8	32.2	445.7	2.5	482.3	37.3	22.6
S _F (2)	466.4	9.3	667.3	5.3	364	28.6	4.8

Table 5: Heavy metal concentrations of soil samples collected from Agbogbloshie scrap market (mg/kg dry weight), third samples.

Soil Samples	Zn	Cr	Cu	Cd	Pb	Co	Ni
S _A (3)	541.2	29.3	5919	16.4	1820	71.1	23.3
S _B (3)	548.9	29.6	4402	12.6	711.9	68	35.2
S _C (3)	546.8	59.4	1986	9.8	973.5	38.1	80.5
S _D (3)	204	10.1	294.1	1.8	164	14.5	2.8
S _E (3)	538.1	32.1	441.1	2.6	482.4	37.4	22.6
S _F (3)	466	9.3	667.1	5.1	364.1	28.8	4.7

Table 6: Heavy metal concentrations of soil samples collected from Agbogbloshie scrap market (mg/kg dry weight).

Soil Samples	Zn	Cr	Cu	Cd	Pb	Co	Ni
S _A	810.53±466.33	41.97±22.03	6291.33±417.69	13.80±4.50	1392.67±745.37	56.10±25.89	22.57±1.27
S _B	899.90±608.04	44.97±26.79	4249.33±265.29	10.73±3.06	642.27±120.61	64.43±6.18	30.47±8.37
S _C	860.17±542.85	57.73±2.80	1852.33±231.52	9.13±1.21	706.60±462.28	31.77±10.63	62.53±31.03
S _D	173.60±52.74	9.57±1.19	226.80±116.65	3.70±3.20	127.83±62.82	17.03±4.47	6.47±6.26
S _E	472.87±108.43	29.53±4.53	317.67±217.79	3.47±1.59	329.90±264.05	30.10±12.56	19.97±4.56
S _F	382.17±145.55	21.07±20.38	1458.47±1370.51	5.13±0.15	382.37±31.73	25.53±5.49	7.67±5.05
Range	173.60-899.90	9.57-57.73	226.80- 6291.33	3.47-13.8	127.83-1392.67	17.03-64.43	6.47-62.53
DTV	140	100	36	0.8	85	20	35
DIV	720	380	190	12	530	240	210

Results expressed as mean ± SD, n = 3.

Leung et al., 2005

New Dutch List, 2000

New Dutch List, 2009

Table 7: Heavy metal concentrations of water samples collected from Agbogbloshie scrap market (mg/L), first samples.

Water samples	Zn	Cr	Cu	Cd	Pb	Co	Ni
W _b (1)	0.064	Nd	0.037	0.014	Nd	Nd	0.677
W _s (1)	0.015	Nd	Nd	0.013	Nd	Nd	Nd

Nd = Not detected (Levels were below detection limit).

Table 8: Heavy metal concentrations of water samples collected from Agbogbloshie scrap market (mg/L), second samples.

Water samples	Zn	Cr	Cu	Cd	Pb	Co	Ni
W _b (2)	0.026	Nd	Nd	0.004	Nd	0.111	Nd
W _s (2)	0.081	Nd	Nd	0.022	Nd	0.103	Nd

Nd = Not detected (Levels were below detection limit).

Table 9: Heavy metal concentrations of water samples collected from Agboglobshie scrap market (mg/L), third samples.

Water samples	Zn	Cr	Cu	Cd	Pb	Co	Ni
W _b (3)	0.026	Nd	Nd	0.003	Nd	0.110	Nd
W _s (3)	0.083	Nd	Nd	0.023	Nd	0.105	Nd

Nd = Not detected (Levels were below detection limit).

Table 10: Mean Heavy metal concentrations of water samples collected from Agboglobshie scrap market with standards (mg/L).

Water Samples	Zn	Cr	Cu	Cd	Pb	Co	Ni
W _b	0.039±0.022	0	0.012±0.021	0.007±0.006	0	0.074±0.064	0.23±0.39
W _s	0.060±0.039	0	0	0.019±0.006	0	0.069±0.060	0
Range	0.039-0.060	0	0-0.012	0.007-0.019	0	0.069-0.074	0-0.23
DTV	0.065	0.001	0.015	0.0004	0.015	0.02	0.015
DIV	0.8	0.03	0.075	0.006	0.075	0.1	0.075

Results expressed as mean ± SD, n = 3.

New Dutch List, 2000

New Dutch List, 2009



APPENDIX B

Reagents and apparatus used

- Sulphuric acid (Concentrated)
- Nitric acid (Concentrated)
- Perchloric acid (Concentrated)
- Hydrochloric acid (Concentrated)
- Distilled water
- 2 mm sieve
- Filter paper
- Spatula
- Funnel
- 100 ml Volumetric flask
- Boiling tubes
- Fume chamber
- Block digester
- Spectrophotometer