HEAVY METALS ACCUMULATI ON IN SOIL, WATER, MAIZE AND CHICKEN AT ORI-ILE BATTERY WASTE DUMPSITE, OLODO, IBADAN, NIGERIA

BY

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ABSTRACT

Battery waste consists of toxic Heavy Metals (HMs) and the Ori-Ile battery waste dumpsite, Olodo, Ibadan has elicited public health concerns. Available literature revealed that maize absorbs and accumulates toxic HMs from polluted soils of irrigated farmlands. But, there is limited information on its accumulation in chicks fed with maize-based feeds at Olodo, where maize is predominantly grown for poultry feed and human consumption. This study was designed to investigate accumulation of some HMs in soil, water, maize and chicks from the vicinity of Ori-Ile battery waste dumpsite, Olodo, Ibadan, Nigeria.

An auto-battery Waste Dumpsite (WD), Ori-Ile, Olodo was purposively selected for the study. One hundred and thirty six topsoil samples were purposively collected (every two months, March 2008 to July 2009) from waste dumpsite and along North, South, East and West (N,S,E,W) directions at 5 m intervals from the edge of WD. Thirty two groundwater samples were collected 25 m away from WD along N, S, E, W directions. Control soil and water samples were collected from Moor Plantation (MP), Ibadan. Soil and groundwater samples were analysed for HMs. Maize was planted in Direction with Highest HMs Concentration (DHHMC) for three months. The maize-parts (roots, stems, leaves, grains) were harvested and analysed for HMs. Broiler feed (18.8-19.7% crude protein) was formulated from part of harvested-grains using standard method. Thirty broilers (day-old) were obtained from a farm, acclimatised for two-weeks on commercial feed and subdivided into two equal groups. The broilers were then fed on Formulated Feed from Harvested Grains (FFHG) and Formulated Feed from Control Grains (FFCG) for additional six weeks. Five chicks from each broiler group were sacrificed at four, six and eight-week old to determine lead, cadmium and iron accumulation in plasma, skin, liver and femur. Similar organs from Free-Range Chicks around WD (FRCWD) and MP (FRCMP) were also analysed for metals. Histopathological analysis of chicks' liver and kidney were done using standard procedure. The HMs in all samples were determined using atomic absorption spectrophotometry. Contamination, Bio-concentration and Bio-accumulation Factors (CF, BcF and BaF) were determined for soil, maize and chicks respectively using standard methods. Data were analysed using descriptive statistics, ANOVA and T-test at p=0.05.

The HMs concentration (mg/kg) from the WD was Pb: 4273.8 ± 1436.7, Cd: 258.4 ± 123.1, Fe: 7910.0 ± 791.5 while that for North: Pb: 4693.8 ± 1107.9, Cd: 274.3 ± 94.8, Fe: 8346.7 ± 740.0; South: Pb: 4353.3 ± 867.0, Cd: 255.2 ± 71.4, Fe: 8189.6 ± 603.5; East: Pb: 4351.3 ± 832.9, Cd: 248.2 ± 65.6, Fe: 8130.0 ± 639.5;West: 4698.3 ± 1020.8, 278.4 ± 86.9, 7851.3 ± 676.8, respectively. These were significantly higher than control (157.0 ± 39.8, 2.2 ± 1.2, 976.3 ± 353.9) and NESREA limits (Pb: 164, Cd: 50). Soil CF values were greater than 6 indicating severe contamination. The HMs concentrations in groundwater (Pb: 0.017 ± 0.015, Cd: 0.003 ± 0.002, Fe: 0.033 ± 0.015mg/L) were significantly higher than control but less than NESREA limits (Pb: 0.01, Cd: 0.005, Fe: 1.0). Lead and cadmium in DHHMC maize-parts were significantly higher than control. Roots had concentration of Pb: 40.95 ± 1.98 and Cd: 2.84 ± 0.19 mg/L. In all maize-parts, B_cF of HMS was < 1. Four-week old FFHG broilers' liver had highest lead, cadmium and iron (0.014 ± 0.002, 0.011 ± 0.003, 302.01 ± 28.023mg/L respectively) where four-weeks>six-weeks>eight-weeks. In FFHG and FRCWD chicks, lead and cadmium were significantly higher than FFCG and FRCMP. Lead and cadmium B_aF values for all chicks were < 1 while iron was > 1. In FRCWD, lead (0.068 ± 0.015) and iron (298.0 ± 8.48) were highest in the liver, while cadmium (0.013 ± 0.002) was highest in the skin. Necrosis, severe diffused hepatic degeneration and interstitial haemorrhages were observed in FFHG and FRCWD chicks.

High accumulation of heavy metals found in the soils of Ori-Ile battery waste dumpsite, Olodo, Ibadan bio-accumulated in maize-roots and in chicken organs.

Keywords: Ori-Ile battery waste dumpsite, Heavy metal accumulation, Free-Range Chicks

Word count: 495

DEDICATION

This work is dedicated:

- To God Almighty (*the Father, the Son, and the Holy Spirit*), who is the pioneer of everything about my life;
- To my ever-loving husband *Pastor Ayooluwaniagbaraemimi Samuel Afolayan*;
- And to my lovely girl: *Temiloluwa Oluwapelumi Afolayan* whose contribution to the success of this research work is indeed immeasurable.
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CERTIFICATION

I certify that this work was carried out by Ononuga Adedotun Onoyinka in the Department of Zoology, University of Ibadan.

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INTRODUCTION

1.1 Generation of Wastes

Globally, various types of activities produce wastes, as well as new types of pollutants (Adie and Osibanjo, 2009). Wastes are unavoidable by-products of most human activities and are materials discharged to, deposited in, or emitted to an environment in such amount or manner that cause a harmful change (Business Dictionary, 2013). They could originate from a number of sources, some of which could be municipal or domestic, agricultural, industrial, medical, automobile scrap, construction or demolition, and or electronic, among others (EEA, 2010).

Generally, there is an increase in the quantity and complexity of generated wastes, due to economic development and rising standards of living (IPCC, 2006, Pandard *et al*, 2006). While demographic expansion, increased industrial and commercial activities have contributed to increased quantities of wastes generated in cities and towns of many countries (Oni, 2010), industrial diversification has also added substantial quantities of industrial hazardous waste into the waste stream (IPCC, 2006). However, all these diverse types of generated wastes are accompanied by potentially severe environmental and human health consequences, if they are not managed properly (EEA, 2010).

Waste has been a problem to mankind from time immemorial, and a growing one that is of major concern to every nation of the world presently (Allende, 2009). Although, developed countries generate much higher quantities of waste compared to developing countries, the management of even small quantities of waste by developing countries could be a significant challenge in certain circumstances (IPCC, 2006). Accordingly,

the disposal of waste is proving to be a major public health issue and a vital factor affecting the quality of the environment more in the developing countries than in developed countries. Higher rates of population growth and urbanization account for the more perverse environmental problem in developing countries (Oseni, 2015). Their low level of technology, which is not sophisticated enough to handle the high rate of waste generation is an added factor (Baum and Parker, 1973).

Furthermore, the rate of waste generation and wastes compositions vary from country to country, depending on the economic situation, industrial structure, waste management regulations and lifestyle and the type of waste generators and land use (IPCC, 2007). Industrialization affects the level of urbanization through increasing population thus, causing a resultant increase in the overall waste generated (Oseni, 2015). Identification of chemical, microbiological or radiological constituents of the generated waste materials is, therefore, very important in order to know the ideal way through which these wastes should be managed (Business Dictionary, 2013; Oseni, 2015).

Management of generated waste often poses challenges, which arise from issues, like resultant lack of disposal options and small land areas, among others (IPCC, 2007). In developing countries, it is difficult to manage waste generation due to increasing population and high level of illiteracy. This makes identification of waste composition crucial for the selection of the most appropriate technology for treatment, taking essential health precautions and the space needed for the treatment facilities (Oseni, 2015).

Recent events in major cities in African countries indicate the enormity of the problem of waste management and of the almost frustrated efforts made by international, federal and state governments, including city authorities and professionals. In Nigeria, like other developing countries, there is a record of increased waste generation and of complex waste management problem (Iriruaga, 2013), which arose from increase in population, urbanization and industrialization (Ogwuche and Yusufu, 2011). The quantity and generation rates of solid wastes in Nigeria have increased at an alarming rate over the years and that in the face of lack of efficient and modern technology for the management of the wastes (Babayemi and Dauda, 2009). Often times, much attention is on solid wastes generated from domestic activities, with little attention is

paid to wastes originating from other sources, like industrial activities and the disposal methods (Oseni, 2015). Neither have they pursued vigorously the main management options, of prevention, minimisation, re-use, recycling, energy recovery and disposal (ETC/SCP, 2013). The disposal of solid waste appears to defy any national solution in Nigeria, with the indiscriminate dumping of waste in open spaces, stream channels, drainages, among others (Ogwuche and Yusufu, 2011). The generation rate, collection and disposal of solid wastes are functions of several factors which if well considered and appropriated could bring the desired solution to the waste management problems in Nigeria (Babayemi and Dauda, 2009).

However, the pursuit of environmental sustainability is an essential part of human well-being (UNEP, 2004), and achieving it requires carefully balancing of human needs with maintaining functioning ecosystems and curbing environmental pollution. This is the goal of safe and proper disposal and management of solid waste (Westlake, 1995). Therefore, improved solid waste management is an important aspect of environmental sustainability, which would reduce environmental vulnerability and offer opportunities for income generation, as well as, health improvement (WHO, 1997).

1.2 Types of Wastes

Quantification and characterization of waste form the basis for management and intervention in many developed countries; but, in developing countries, little priority is on systematic surveying of generated waste, the quantities, characterisation and even disposal options (IPCC, 2007). The commonest kinds of waste can be classified into four types namely, municipal, industrial, agricultural and nuclear (Alloway, 1995). Similarly, according to IPCC (2006), four major categories of wastes are municipal solid waste, industrial waste, agricultural waste and hazardous waste. Also, two broad classifications are hazardous wastes, which comprise some components of industrial, agricultural and mining wastes and municipal solid wastes of household and other institutional wastes (Oseni, 2015). Other waste types apart from those listed above are construction and demolition waste, mining waste, and waste from electrical and electronic equipment (WEEE), biodegradable municipal waste, packaging waste and wastes from end of life vehicles (ELVs) and tyres (ETC/SCP, 2013).

Hazardous or harmful wastes are those that potentially threaten public health or the environment. Such waste could be inflammable, reactive, corrosive or toxic. Most hazardous wastes are by-product of a broad spectrum of industrial, agricultural and manufacturing processes, nuclear establishments, hospitals and health-care facilities. Primarily, high-volume generators of industrial hazardous wastes are chemical, petrochemical, petroleum, metals, wood treatment, pulp and paper, leather, textiles and energy production plants, among others. Small and medium sized industries that generate hazardous wastes include auto and equipment repair shops, electroplating and metal finishing shops, textile factories, hospital and health-care centres, and dry cleaners and pesticide users.

The types, quantities and sources of hazardous wastes vary significantly from country to country and are influenced by the extent and diversity of industrial activity (IPCC, 2007). Hazardous wastes are generated in large quantities as a result of significant quantities of toxic chemicals being consumed in different areas due to rapid development in agriculture, industry, commerce, hospital and health care facilities. Currently, there are about 110 000 types of toxic chemicals commercially available, and each year, another 1 000 new chemicals are added to the market for industrial and other uses (IPCC, 2007). The availability of robust data on the generation of hazardous waste is limited by the reliability of information on the quantities and types of hazardous waste produced at the country level. This is due to a variety of reasons, including the lack of qualified personnel to undertake necessary assessment, the reluctance of industries to provide process information and a poor appreciation of the extent to which generated waste is hazardous. Where data is available, significant difficulties are encountered in seeking to draw international comparisons due to differences in classification and definition of hazardous waste from country to country within in the region (IPCC, 2007).

The main disposal route for hazardous waste is landfill, incineration and physical or chemical treatment. On the recovery side, a significant proportion of hazardous waste is recycled or burned as a fuel, since it can present a potential risk to both human health and the environment. In many countries, it is required by law to involve the appropriate authority to supervise the disposal of such hazardous waste (EST, 2008). Hazardous waste is typically the subject of special legislation and requires special

management arrangements to ensure that hazardous waste is kept separate from and treated differently to non-hazardous waste (ETC/SCP, 2013).

Industrial solid waste comprises a wide range of materials of varying environmental toxicity (IPCC, 2007; ETC/SCP, 2013). The absence of a regularly up-dated and systematic database on industrial solid waste ensures that the exact rates of generation are largely unknown (IPCC, 2007).Also, industrial solid waste generation varies between developing countries. But, the existing industrial solid waste collection, processing and disposal systems of many countries are grossly inadequate. The increase in the rate and amount of generated waste would pose very serious challenges (IPCC, 2007). Thus, the manufacturing industry has a central role to play in the prevention and reduction of waste as the products that they manufacture today become the wastes of tomorrow. Manufacturers can achieve this by considering the impacts of their products throughout its life at the design stage of the product; using manufacturing processes that minimise material and energy usage; eliminating or reducing where possible the use of substances or materials hazardous to health or the environment; and manufacturing products in such a way that they last longer and may be recycled or reused at the end-of-life stage (ETC/SCP, 2013).

Other types of wastes include construction and demolition wastes, which result from activities, such as, the construction of buildings and civil infrastructure, total or partial demolition of buildings, road planning and maintenance. In some countries even materials from land levelling are regarded as construction and demolition wastes. Mining wastes arise from prospecting, extraction, treatment and storage of minerals. Wastes from electrical and electronic equipment (commonly referred to as WEEE) consist of end of life products and comprise a range of electrical and electronic items whose sources are all users of electrical and electronic equipment from householders, to all kinds of commercial and industrial activities. Biodegradable Municipal Waste (BMW) is waste from households and commercial activities that is capable of undergoing biological decomposition. Food waste and garden waste, paper and cardboard are all classified as biodegradable municipal waste (ETC/SCP, 2013).

Packaging wastes can arise from a wide range of sources including supermarkets, retail outlets, manufacturing industries, households, hotels, hospitals, restaurants and transport companies. End-of-life vehicles are defined as cars that hold up to a

maximum of eight passengers in addition to the driver; trucks and lorries that carry goods up to a maximum mass of 3.5 tonnes. Consequently, sources of wastes from end-of-life vehicles range from households to commercial and industrial vehicles. Such vehicles comprise numerous different materials. Approximately 75% of the weight of a car is made up of steel and aluminium, most of which is recycled. Other materials often present, if not properly managed, may cause significant environmental pollution while the remainder could be recycled, incinerated or landfilled (ETC/SCP, 2013).

Municipal solid waste is the waste generated from households, offices, hotels, shops, schools and other institutions (IPCC, 2007; Oseni, 2015). The major components of these wastes are food waste, paper, plastic, rags, metal and glass, although demolition and construction debris is often included in the collected waste, as well as small quantities of hazardous waste, such as electric light bulbs, batteries, automotive parts and discarded medicines and chemicals (IPCC, 2007). The generation rates and components of municipal solid wastes vary from place to place and from season to season and have a strong correlation with the levels of economic development and activity (IPCC, 2007). Municipal wastes have been traditionally landfilled; that is why, it is the predominant management option in most countries. However, some countries have taken significant steps away from landfill. Alternatives offered include incineration (increasingly with recovery of energy), composting and recycling of glass, paper, metal, plastics and other materials (ETC/SCP, 2013).

Agricultural wastes are wastes generated from agricultural activities and a form of hazardous wastes. These have increased due to expanding agricultural production, in terms of increased quantities of livestock waste, agricultural crop residues and agro-industrial by-products. This category of wastes also comprises varying components based on the nature of the agricultural practices and type of products (IPCC, 2007). Agricultural wastes comprises organic wastes (animal excreta in the form of slurries and farmyard manures, spent mushroom compost, soiled water and silage effluent) and other types of wastes, such as plastic, scrap machinery, fencing, pesticides, waste oils and veterinary medicines (ETC/SCP, 2013). There are a number of methods used to treat agricultural waste. These include spreading the waste on land under strict conditions, anaerobic digestion and composting (ETC/SCP, 2013).

In addition, there are a number of potential environmental impacts associated with agricultural wastes, if it is not properly managed. Run-off of nutrients to surface waters is one of the disposal methods that can cause over enrichment of the water body. Leaking and improper storage of agricultural waste can also pose a serious threat to the environment, should the waste reach surface waters. In addition, farming activities can give rise to emissions of ammonia and methane, which can cause acidification and contribute to greenhouse gases emissions (ETC/SCP, 2013).

1.3 Industrial Wastes: Generation and Handling

Industrialization has led to a tremendous increase in the amount of waste thrown into the environment (Inuwa, 2004). Industrial wastes vary in composition and depend on the industries from where the wastes are originating (Kumar *et al*, 2012). Most industrial wastes consist of toxic components that should not come in contact with living organisms. In fact, these toxic components in the different industrial wastes often generate environmental pollutants. However, it is their inappropriate disposal that gives rise to unmanageable and costly ecological problems (Manali, 2010).

Industrial waste is the waste produced by industrial activity and any material that is rendered useless during a manufacturing process (Maczulak, 2010). They include solid, semi-solid, liquid, or gaseous, unwanted or residual materials from an industrial operation (Business Dictionary, 2015). Industrial waste may be toxic, ignitable, corrosive or reactive and if improperly managed, they can pose dangerous health and environmental consequences (Texas Environmental Almanac, 2015). Mismanagement of industrial waste has resulted in polluted groundwater, streams, lakes and rivers, as well as, damage to wildlife and vegetation (EPA, 1986). Undesirably, high levels of toxic contaminants have been found in animals and humans, who are continually exposed to such waste streams (Washington, DC: GAO Report, 1992).

Industrial waste disposal commands a relatively large share of attention, because many industrial wastes are toxic and hazardous (Adeagbo, 2011). The use of open land as dump sites by manufacturing industries in developing countries without appropriate prevention of environmental hazards has resulted in prominent levels of waste and disposal effluents (Adegoke *et al*, 2009). This has resulted in the contamination of soil

and the exposure of human populations to environmental and health hazards (Adegoke *et al*, 2009).

Numerous industrial activities, including automobile battery production, landfilling of industrial waste among others have often resulted in the accumulation of metals in the environment (EPA, 1998; 2000; Hussein *et al*, 2005; Gardea-Torresdey *et al*, 2005; Kumar *et al*, 2012). Consequently, both soil and aquatic environments have been contaminated with heavy metals (Kumar *et al*, 2012). This contamination thus poses serious health threats to humans and animals, as these heavy metals tend to persist in the environment indefinitely (European Union, 2002). This kind of contamination also presents a challenge, as the presence of heavy metals in soils and water bodies leads to serious problems because they cannot be biodegraded (European Union, 2002).

1.4 The Impact of Heavy Metals

Heavy metals are thus commonly defined as those having a specific density of more than 5 g/cm^3. The main threats to human health from heavy metals are associated with exposure (Jarup, 2003). The many uses of heavy metals in several applications lead to their wide distribution in soil, silt, waste and waste water (Kumar *et* al, 2012). Such pollution of the environment arises as a result of many human activities, largely industrial, although such sources as agriculture and sewage disposal also contribute (Kumar *et* al, 2012). The majority of the sources are originated by human actions like metal manufacture and mining industries with storage, disposal and transportation problems (Glick, 2003).

Although several adverse health effects of heavy metals have been known for a long time, exposure to heavy metals continues, and is even increasing in some parts of the world, in particular in less developed countries, though emissions have declined in most developed countries over the last 100 years (Jarup, 2003). Emissions of heavy metals to the environment occur via a wide range of processes and pathways, including the air, surface waters and soil; subsequently, ground-waters and crops (Jarup, 2003).

The concentration of heavy metals in soil is increasingly becoming an issue of global concern. This is because soils constitute a crucial component of rural and urban environments, and can be considered as a very important ecological crossroad in the landscape (United States Department of Agriculture, 2000; Adegoke *et al*, 2009).

Heavy metal contamination can be a consequence of industrial activities that eliminate residues in the soil that in long term promote their accumulation (Glick, 2003). Manufacturing, mining, and the use of several products, such as batteries, pesticides, paints, industrial waste, and land application of industrial or domestic sludge can result in heavy metal contamination of urban and agricultural soils (United States Department of Agriculture, 2000). Heavy metals contamination of soil also occurs as a result of anthropogenic activities, such as, smelting procedures, and agriculture, apart from those arising from natural activities (Navarro et al., 2008; Brumelis et al., 1999; Vaalgamaa and Conley, 2008; Cortes et al., 2003). However, chemical and metallurgical industries are the most important sources of heavy metals in the environment (Adegoke *et al*, 2009).

Heavy metals occur naturally, but rarely at toxic levels (United States Department of Agriculture, 2000). Potentially contaminated soils may occur at old landfill sites particularly those that accepted industrial wastes, industrial areas where chemicals may have been dumped on the ground, areas downwind from industrial sites, among others (United States Department of Agriculture, 2000). Once these metals are introduced into the environment, being non-biodegradable, it is very difficult to eliminate them from the environment, except for mercury and selenium, which can be transformed and volatilized by microorganisms (United States Department of Agriculture, 2000; Muhammed *et al*, 2011).

All trace elements are toxic to living organisms at excessive concentrations due to formation of complex compounds within the cell (Adegoke *et al*, 2009; Muhammed *et al*, 2011). However, some are essential for normal healthy growth and reproduction by plants and animals at low but critical concentrations, and deficiencies in these essential trace elements can lead to disease and even death of the plant or animal (Adegoke *et al*, 2009). The essential trace elements include Cobalt, Chromium, Copper, Manganese, Molybdenum, Nickel, Selenium and Zinc while Silver, Arsenic, Barium, Cadmium, Mercury, Lead, and Antimony have no known essential function but cause toxicity above certain tolerance level (Adegoke *et al*, 2009).

Excess heavy metal accumulation in soils is toxic to humans and other animals (United States Department of Agriculture, 2000). The most important heavy metals with regards to potential hazards and the occurrence in contaminated soils are Arsenic,

Cadmium, Chromium, Mercury, Lead, and Zinc (Alloway, 1995; Asio, 2009). The concentration of these toxic elements in soils may be derived from various sources, including anthropogenic pollution, weathering of natural high background rocks, and metal deposits (Asaah and Abimbola, 2006). Hot spots of heavy metal pollution are located close to industrial sites, around large cities and in the vicinity of mining and smelting plants. Consequently, agriculture in these areas faces major problems due to heavy metal transfer into crops and subsequently into the food chain (Asio, 2009).

Heavy metals get accumulated over time in soils and plants and could have a negative influence on physiological activities of plants, determining the reductions in plant growth, dry matter accumulation and yield (Adegoke *et al*, 2009). Some of the heavy metals such as lead, cadmium, and mercury are toxic to plants and animals, even in trace concentrations (Ioan et al., 2008). The exposure to heavy metals is normally chronic due to food chain transfer (United States Department of Agriculture, 2000). Heavy metal pollution of soil enhances plant uptake causing accumulation in plant tissues and eventual phyto-toxicity effects. This can change plant communities (Gabriella et al., 2005).

Exposure to some heavy metals in the soil can also be harmful to humans and the health effects cut across different gender and ages (Agusa et al., 2006; Needleman et al., 1990). These metals when taken into the body are capable of causing serious health problems especially by interfering with the normal body functions (Kumar *et al*, 2012). Some of these metals like iron are useful to the body in low concentrations, but are toxic at high concentrations, while others like cadmium and lead have no biological functions and are highly toxic; disrupting bodily functions to a large extent. They disrupt bodily functions by accumulating in vital organs and glands in the human body, such as, the kidney, liver, bone, heart and brain (Kumar *et al*, 2012). They also displace vital nutritional minerals from their proper place in the body to provide biological functions (European Union, 2002).

The main strategies of pollution control are to reduce the bioavailability, mobility, and toxicity of metals (Muhammed *et al*, 2011). Methods for remediation of heavy metal-contaminated environments include physical removal, detoxification, bioleaching, and phytoremediation (Muhammed *et al*, 2011). Thus, preventing heavy metal pollution is critical and it is the best method to protect the environment from contamination by

heavy metals. This is because cleaning contaminated soils is extremely expensive and difficult (United States Department of Agriculture, 2000).

1.5 Pollution Factors and Ecosystem Degradation

The way in which humans relate to the environment has called for great concern from both ecologist and environmentalists around the globe. Over time, the actions of humans have led to unimaginable damage to the ecosystems, especially with regards to waste mismanagement; and this has led to problems that cut across the different levels in the food chain (Irina and Reller, 2011). As a result of these, human health and existence is at risk due to the different negative environmental issues arising (Abbas *et al*, 2006).

One prominent negative environmental issue is pollution. The development of new technologies has made environmental pollution a more outstanding problem in the world (Irina and Reller, 2011). As earlier noted, the magnitude of pollution in the natural environment has increased due to advanced industrial and agricultural practices (Shingara *et al*, 1979). Accordingly, toxic elements can be found in any part of the environment (Satarug *et al*, 2003; Pacyna *et al*, 2006) and contaminations of various sources of food for humans have been reported (Nwude *et al*, 2011).

Poor waste management procedures resulting from the unguided dumping, deliberate application and accidental discharge of large amount of wastes into the environment, without thorough consideration of its resultant effects on the biota community has amplified the incidence of ecosystem pollution (Reiss and Chapman, 2000). It has a wide array of effects that cut across the economy, health, natural resources and social status of any living community (USEPA, 2011). Its social implications are mostly felt by the low-income communities because of their level of ignorance, lack of organization as well as less involvement in municipal decision making processes (USEPA, 2005).

Similarly, environmental pollution has a dramatic negative effect on natural resources. It has been established that ineffective management of wastes from industrial and urban activities could pollute soils, leading to the accumulation of toxic metals in the soils, transferred to plants and consequently into animals (Swarup *et al*, 2006). The

non-biodegradable materials in improperly disposed wastes are lethal to life in the soil, while its accumulation in soil poses a threat to plant and animal life (Manali, 2010).

The most common forms of pollutions are air, water and land pollutions (Conserve Energy Future, 2009). Severe environmental degradation appears to be threatening the long-term development prospects of countries all over the world, particularly the developing ones, such as, Nigeria (Adenuga e*t al*, 2005). Uncontrolled open dumping on the peripheries of many cities has resulted in the degradation of valuable land resources and the creation of long-term environmental and human health problems (Oni, 2010). Indiscriminate dumping could also lead to the contamination of surface and groundwater supplies, while open burning of wastes contributes significantly to urban air pollution.

The concern over soil pollution stems primarily from health risks, which results from direct contact with the contaminated soil, vapours from the contaminants and from secondary contamination of water supplies within and underlying the soil (USEPA, 2011). Also, due to the heavy metals constituent of some wastes, environmental risk due to soil pollution is of particular importance for agricultural areas. This is because of the potential harm that such heavy metals mete out to human health (Nwegoha and Kihampa, 2010). Consequently, these metals enter the food chain in elevated amounts and affect food quality and safety; thus, posing threat to a country's food production (Alloway, 2004).

Ecotoxicological issues associated with the food chain protection and guarantee of the food chain safety assurance are issues of urgent attention on analysis of different concentration of accumulated toxic materials within the living organisms consumed as food (Zraly *et al*, 2008). However, the non-living materials within the environment is also of concern, because of their interconnection with the living environmental resources (Smith, 2008).

1.6 Movement of Pollutants along Food Chain

The effects of soil pollution go far into affecting food webs, as well as, other important aspects of the ecosystem and they could also cause other effects in connected ecosystems. From polluted soils, heavy metals are gradually dispersed into the different parts of the environment and bio-accumulate as well as bio-magnify in food

chains (Alloway, 2004). Therefore, their levels might reach or exceed toxic limits, even when found in low concentrations in environmental samples (Caggiano *et al*, 2004; Yusuf *et al*, 2003).

One other major effect of heavy metals is the ecosystem imbalance, due to its negative impact on the fauna and flora inhabiting terrestrial ecosystem (USEPA, 2011), while other effects are health hazards (United States Department of Agriculture, 2000; Manali, 2010).

Two terms are essential in the movement of pollutants along the food chain and these are bio-accumulation and bio-magnification. Bio-accumulation refers to the manner pollutants enter a food chain, while bio-magnification is the susceptibility or propensity of pollutants to concentrate as they move from one trophic level to the next (Mader, 1996). These two phenomena mean that even small concentrations of chemicals in the environment can find their way into organisms in high enough dosages to cause problems and for bio-magnification to occur, the pollutant must be long-lived, mobile, fat soluble and biologically active (Mader, 1996). Heavy metals are among the toxic pollutants that have the potential to bio-magnify (Mader, 1996).

Soil serves as an essential link in the water cycle that plants require because the minerals they need do not become available to them unless dissolved in soil water (Finkl, 2008). Therefore, toxic pollutants can dissolve in polluted soil water, while plants absorb nutrients required for healthy life from the soil, those dissolved toxic pollutants are also absorbed along with the mineral requirements (All Recycling Facts, 2012). As a result, these contaminate the plants growing on polluted soil and plants, being producers, are the first point of call in the food chain. Therefore, any pollutant that is absorbed into plant could bio-magnify as it moves up among different consumers in a single food chain or interconnected food web, as these toxic pollutants are transferred from one level to another in the food chain; consequently, they are most often non-biodegradable, they increase in concentration in each different consumer and could build up to such levels that are far beyond the permissible safe level recommended in most countries.

In cases of serious soil contamination, entire populations of organisms, usually lower down in the food chains, which come into direct contact with the soil, could be

destroyed and this could in turn affect the animals higher up food chains (All Recycling Facts, 2012). In cases of less severe soil contamination, the organisms lower down the food chains may bio-accumulate the toxic substances in their bodies, and the effects of the toxins may bio-magnify in the higher animals as you go higher up the food chains (All Recycling Facts, 2012). Thus, animals raised around dumpsites, which forms an important part of the community food chain could serve as a link through which the toxic components of the disposed wastes get to humans.

Erosion of soil by rainwater could wash soil pollutants into nearby water bodies, thus causing aquatic pollution. This kind of pollution is lethal to the aquatic flora and fauna (Manali, 2010). Potentially greater threats are posed by the infiltration of soil contaminants into groundwater aquifers used for human consumption, sometimes in areas apparently far removed from any source of above ground contamination; thus contaminating the underground water resources (Manali, 2010). According to Rapti-Caputo and Vaccaro (2006), the contamination of groundwater by leachate is recognized as a serious socio-economic and environmental problem in many countries.

This chain of pollutions most often gets toxic pollutants back to humans. Humans are omnivore and they occupy the highest position in the food pyramid. This thus expose humans to increase concentration of pollutants especially through many feeding channels and pollutants such as the heavy metals are significantly toxic because of their accumulative nature in the different body parts and they lead to unwanted side effects (Jarup, 2003; Sathawara *et al*, 2004; Yusuf *et al*, 2003).

In addition, they also have detrimental labile nature along with their toxicity and bioaccumulation potential, which often result in the different effects on human beings (Zaidi *et al*, 2005; Yusuf *et al*, 2003). Primary effects of pollution such as death occur immediately after contamination might have taken place. But, secondary effects may be delayed or may persist in the environment into the future, perhaps going unnoticed for many years (Manali, 2010).

1.7 Impact on the Health of Soil, Plants and Animals

The health consequences that arise from exposure to pollutants through soil contamination vary greatly and depend on the pollutant type, pathway of attack and vulnerability of the exposed population (Van de Merwe *et al*, 2010). Environmental

pollutants also have significant effect on terrestrial plants, which serve as the primary producers of food for other living organisms. When there is contamination of soil with toxic substances, substantial changes occur in the chemistry of the soil, which in turn affects the well-being of plants and animal life living in the soil, as well as the ecosystems that the soil supports (All Recycling Facts, 2012). Plants grown on a polluted land could absorb toxic elements along with their mineral nutrients and thus, serve as a means through which toxic pollutants are transferred up the food chain (Numberg, 1984; Yusuf *et al*, 2003; Rattan *et al*, 2005; USDA-NRCS, 2000).

The non-biodegradable pollutants in the improperly disposed wastes are toxic to the living organisms in the soil and their accumulation in soil poses risk to plant and animal life (Manali, 2010). The toxic metals in the soil pollutants could be transferred into plants and consequently into animal (Swarup *et al*, 2006). Pollutants, such as, heavy metals have been found to have several effects on living organisms. One of the major effects is the ecosystem imbalance, due to its negative impact on the fauna and flora inhabiting terrestrial ecosystem (including reduction in species richness of such ecosystem) (USEPA, 2011). Other effects are attributed to their being as a source of health hazards (USDA-NRCS, 2000; Manali, 2010).

When heavy metal wastes are discarded indiscriminately, enhanced soil levels can result in increased phyto-extraction and assimilation by plants (Numberg, 1984; Yusuf *et al*, 2003; Moreno *et al*, 2005; Benson and Ebong, 2005; Udosen *et al*, 2006; Nsikak, 2006). These heavy metals, through such plants, may inadvertently enter the food chain posing considerable health risks to both humans and animals (Numberg, 1984; Banuelos and Mayland, 2000; Ellis and Salt, 2003; Pillay *et al*, 2003; Moreno *et al*, 2005; Nsikak, 2006). Recent studies have indicated that crops raised on metal contaminated soil accumulate metals in concentrations excessive enough to cause clinical problems both to humans and animals that consume these metal rich plants (Rattan *et al*, 2005; Nsikak, 2006).

In the present day Nigeria, the cultivable agricultural farmlands are increasingly being polluted by heavy metals, such as, lead and cadmium (Nsikak, 2006). Heavy metals are classified with other trace metals, some of which are considered as essential plant nutrients (Yusuf *et al*, 2003). Most heavy metals are of considerable health and

environmental concern because of their toxicity and bio-accumulative behavior (Omgbu and Kokogbo, 1993; Ajibola and Ozigis, 2005; Nsikak, 2006).

The consumption of contaminated animal tissues, which form an important part of the human nutrition, can be detrimental (Lazarus *et al*, 2005). Animals raised by humans for food could be exposed to toxic contaminants either through their diets, water or the air they breathe (UNEP, 2008). But, once in animals, toxic elements' levels in their tissues are organ specific such that the internal organs, like the liver and kidney, often accumulate higher metal concentrations than most of other parts consumed as foods (Villar *et al*, 2005).

Also, pollutants, such as lead (Pb), can also leach into water supplies (Blacksmith Institute, 2011), often used for farm or garden irrigation along with other domestic needs of humans. These also serve as route through which the toxic metals enter into the food chain. In addition, when humans and their livestock consume polluted surface and underground water, there is the tendency of transfer of the pollutants from such water into the consumer (Stewart *et al*, 1989).

1.8 Ori-Ile Olodo, Ibadan Open Battery Waste Dumpsite

An urban city in Nigeria, namely Ibadan has such history of waste disposal at the former outskirt of the city in a particular community, called Olodo. However, the action of the waste contractors of a now closed down lead acid battery manufacturing company, known as West African Battery Industry, which used to produce the battery known as Exide Battery, between the late 1980s and the late 2000 prompted public health concerns. This is because the company used several places within the area as open dumps (Oyediran and Aladejana, 2011; Adeagbo, 2011). Regrettably, increase in population and expansion of Ibadan city in recent times resulted in the allocation of these previously used open waste dumps for housing development (Oyediran and Aladejana, 2011).

Ori-Ile, Ikumapaiyi area of Olodo is one of the several areas used as open dump by the West African Battery Industry and its non-formal lead recovery operation. This particular area is now developed and inhabited, but there was an outcall for help; based on the series of environmental challenges the inhabitants were facing. Oyediran and Aladejana (2011) reported that in 2006, there was a general outbreak of diseases

among the inhabitants of the Olodo village, the cause of which was attributed to lead poisoning from the wastes. Also, there were reports of damage to crops, poultry, aquatic life and abortions in goats. As a result, the inhabitants of the community alerted Oyo State Ministry of Environment, which intervened, together with the Federal Government (Sridhar *et al,* 2012). The company, though eventually closed down, was compelled at that time to carry out excavations on the site for proper remediation of the contaminated soil (Oyediran and Aladejana, 2011).

However, the effects of the dumped battery wastes are still persistent in the area. This is because the improper disposal of this kind of wastes usually has prolonged consequences on the ecosystem into which they are dumped (Adie and Osibanjo, 2009; Iwegbue *et al*, 2006; Chen *et al*, 2009; Oyediran and Aladejana, 2011). The reason is that the wastes contain mixtures of different types of chemicals that were used during the manufacturing process. The chemicals consist of components that are not environmental friendly, whether singly or in combination (Hartley *et al*, 2009; Zhao *et al*, 2009). Consequently, they result in a lot of damages to the ecosystem generally and to its different components individually (Irina and Reller, 2011).

1.9 Justification for the Study

Although different studies have reported heavy metal levels of other areas in Olodo (Oyediran and Aladejana, 2011; Adeagbo, 2011; Olusoga and Osibanjo, 2007; Adie and Osibanjo, 2009; Sridhar *et al*, 2012), there is limited information on the varied health hazards they cause, especially in dumpsites further away, such as Ori-Ile Olodo community, which have not been reported. Similarly, previous studies stopped short of an in-depth study of the link along the food chain and the health hazards on residents of Ori-Ile Olodo Community and their domestic animals.

It is well known that battery wastes consist of different toxic components, some of which are the non-biodegradable and could accumulate in soil. The prior disposal of these battery wastes on Ori-Ile Olodo undeveloped land would definetly have impacted negatively on the soil. Also, from cursory observations, the waste dumpsite area is bare with scanty vegetation, despite the fact that the surrounding area is furnished with diverse arrays of plants. The most prominent vegetation on the waste dumpsite is the

corn grasses, which are tolerant and accumulate heavy metals in high concentration (Ononuga, 2005).

Also, Ori-Ile Olodo residents predominantly grow maize for both human and animal consumption. Some of them utilize their harvested maize seeds for constituting feed for their domestic animals, especially chicken, while their domestic ruminants feed on the harvested maize leaves. Available literature revealed that maize absorbs and accumulates toxic heavy metals from polluted soils (Olusoga and Osibanjo, 2007). This informed the choice of maize in the study, so as to determine the concentration of the heavy metals in the different parts of the maize plant that could have been absorbed from the polluted soil from battery wastes. In addition, although some of the previous studies in Olodo touched on concentration of some heavy metals, such as, lead and cadmium, on the whole maize plants (Olusoga and Osibanjo, 2007), the present study determined the concentration of these two heavy metals and iron on different parts of maize plant, namely, the roots, stem, leaves and seeds. The study was to provide more information on these parts of the maize plant in which the heavy metals are most likely to be highly accumulated and determine whether consumption of the maize by residents of Ori-Ile Olodo community and their domestic animals could lead to toxicity.

Furthermore, there is limited information on heavy metal accumulation in chicks (either raised as scavengers or fed with maize-based feeds) at Ori-Ile Olodo area. This study thus was designed to also determine the concentration of heavy metals in chicks of Ori-Ile community. Being the first of its kind, it would serve to bridge the gap and inform residents, scientists and policy makers on the tendency of domestic animals, such as, chicks raised within a polluted community to accumulate potent heavy metals through their diets and water. The use of broiler chicks, to determine heavy metal concentration in the organs of the chicks was to ascertain their uptake and accumulation from the cultivated maize seed diet, which is essential in providing information on the tendency of uptake of metal from polluted food source. The broiler chicks were used because of their wide use in literature for toxicity study (Bakalli *et al*, 1995; Muhammad and Oloyede, 2009; Clement *et al*, 2010) and based on an observation that majority of majority of Ori-Ile Olodo residents raised them; as such,

they may become the connecting chain between the polluted and the unpolluted communities.

Moreover, although, several works have been done on measuring the toxic levels of different heavy metals in many polluted sites (Udosen *et al*, 1990; Yahya, 1994; Benson, 2004; Zauyah *et al*, 2004; Nsikak, 2006; Adie and Osibanjo, 2009; Olusoga and Osibanjo, 2007; Oyediran and Aladejana, 2011), none has concretely addressed the study in line with the spread of some toxic heavy metals from the point of pollution to furtheraway parts of the community. In addition, most of the studies have not really looked at the linkage between the heavy metal concentration in the polluted soil and those of other components of the environment, in particular representative organisms of the food chain, such as maize and chicken.

Furthermore, deriving from the fact that rain water produces run-offs which washes the soil of the dumpsite downslope into the stream and residents use the stream water to do different domestic activities, including garden irrigation, especially when water become rare, it became mandatory/necessary to determine the concentration of the three metals in the stream water also. Also, residents of Orile-Ile Olodo drink underground well water, use it for cooking and for their domestic animals, among others. These wells are situated in the vicinity of the waste dumpsite; hence, the need to determine the concentrations of the heavy metals in the most frequently consumed well water.

In general, the present study at Ori-Ile waste dumpsite and surroundings determined the levels of selected heavy metals, namely lead, cadmium and iron in the soil of the waste dumpsite and surroundings, the underground water, surface water, maize plant and chicks of Ori-Ile Olodo community in order to know the extent to which heavy metal components of the discarded battery wastes have been dispersed, absorbed and accumulated within the Ori-Ile Olodo community.

Basically, these form the main thrust of this research study, which when completed the following other findings are of utmost value, namely:

- The determination of concentration of heavy metals, namely lead, cadmium and iron in the soils of both the waste-dump and its surrounding to show the extent of the spread of the waste components. This information is essential as it

will prove useful in the selection of suitable remediation method and how far into the community such should be applied.

- Determination of the concentration of the heavy metals in both underground and surface water to provide information on water as one of the routes of exposure of the residents. This will help decision makers in controlling exposure by preventing the intake and use of such water if found polluted. This is particularly important if the metal level is found to exceed standard regulatory limits.
- Determination of the concentration of the heavy metals in the plants grown within the area to provide information on the uptake of the heavy metals from the soil. This is essential in that it will further inform on the potential of such plants to bio-accumulate pollutants and gradual and harmful link in the food chain. This information will help lawmakers put preventive measures in place to restrain residents from growing or consuming such plants and the type of remedial measures that perpetrators (industrialists) of such acts will put in place.
- Assessment of heavy metals in chicks being raised within the area in addition to broilers fed with food grown in the area to provide information on the ability of chicks to bio-accumulate and bio-concentrate the metals in their different internal tissues or organs. This could help to educate the residents on parts of chicks that could serve as store for the absorbed toxic metals and from which higher risk of toxicity could arise when consumed.

1.10 Research Objectives

The main objectives of the study are two folds: to ascertain the spread of heavy metal components of the battery wastes beyond the dumpsite soil to the surrounding areas along the gradient points of the study area, through the analysis of the topsoil, well water and stream water, and to confirm any active uptake and transfer of the heavy metals into maize plant and chicks.

The study was, therefore, on the following eight (8) sub-objectives, which were to:

a) Determine the total concentration of lead (Pb), cadmium (Cd) and iron (Fe) in the topsoil samples from Ori-Ile Olodo battery waste dumpsite and along

North, South, East and West directions at 5 m intervals from the edge of the waste dumpsite.

b) Determine the total concentration of lead (Pb), cadmium (Cd) and iron (Fe) in the groundwater samples collected from four (4) wells, each collected within 25 m away from waste dumpsite along the four cardinal points, of North (N), South (S), East (E), and West (W) directions.

c) Determine the total concentration of lead (Pb), cadmium (Cd) and iron (Fe) in the randomly selected upstream, midstream and downstream water samples, taken from the main surface water that flows perpendicular to the base of the hill on which the battery waste-dump site was located (Omi-Stream).

d) Determine the total concentration of lead (Pb), cadmium (Cd) and iron (Fe) in the different parts of the maize (leaves, stems, maize-grains and roots) that was planted in the direction with highest heavy metals concentration and observed for a period of three (3) months.

e) Determine the total concentration of lead (Pb), cadmium (Cd) and iron (Fe) in plasma, skin, liver and femur of four-, six- and eight-week old broiler chicks that were bought as day olds from a reputable farm.

f) Determine the total concentration of lead (Pb), cadmium (Cd) and iron (Fe) in plasma, skin, liver and femur of resident free-range chicks purchased from around the battery waste dumpsite, in comparison to those observed above in (e)

g) Determine the bio-accumulative effects of exposures to heavy metals in the contaminated maize fed broiler chicks as against the scarvenging resident chicks; using their liver and kidney for histopathologic assesment and their plasma for haematologic analysis.

h) Determine the contamination, bioconcentration and bioaccumulation factors of the different samples as well as the growth rate of the broiler chicks over the period of exposure.

CHAPTER TWO

LITERATURE REVIEW

2.1 Battery Recycling and Pollution in Nigeria

Nigeria, like other developing nations, has experienced tremendous growth in population and development in recent times (Uchegbu, 1998). These have led to various degrees of pollution that are further manifested in the disruption of the trophic structure, energy flow, and chemical cycling of the nation's natural resources and in its functioning ecosystems (Campbell, 1999; Campbell and Reece, 2005).

The Nigerian ecosystems are undergoing biodiversity depletion, through continual subjection to pollution from improperly discarded potent wastes, in particular those generated by different manufacturing industries in the course of production of useful technological items, like automobile batteries (Oyediran and Aladejana, 2011; Adie and Osibanjo, 2009). These industries utilize indiscriminately toxic chemicals, without putting into consideration the means of discarding the wastes that will be generated; thus, causing both ecological and socio-economic problems (USEPA, 2005).

The wastes produced from battery production and utilization is one of the causative agents of ecological and socio-economic problems (Adie and Osibanjo, 2009). Some of the components of these wastes, when improperly discarded, pose health challenges to biota, especially humans, and could also result in ecological imbalance and stress (Makino *et al.*, 2010). Apart from these effects, the recovery of components of used batteries (e.g. lead) also impact adversely on the environment, despite its being a viable and profitable business for many people in the developing countries (Figure 2.1). This is because recycled lead is a valuable commodity; hence, the market for reclaiming secondary lead (Figure 2.2) has been growing. The Basel Convention, 2010 also noted that many developing countries have entered the business of buying used

Figure 2.1: Used Lead Acid Batteries Recovery Dumpsite

Figure 2.2: Reclamation of secondary lead from used battery components in Nigeria

lead acid batteries (ULABs) in bulk in order to recycle them for lead (Basel Convention, 2010).

The recycling and smelting operations are often located in densely populated urban areas of developing countries with limited (if any) pollution controls. In many cases, the local recycling operations are not managed in an environmentally sound manner, which results in the release of lead in critical quantities into the local environment and ecosystems and lead contaminations of over 12 million people throughout the developing world (Blacksmith Institute, 2011).

About the same observation applies to Nigeria, where manufacturers of automobile batteries have often times no proper waste management plan for the enormous and highly toxic wastes they generate in the course of production. That's why they usually engage the services of cheap and non-registered waste managing agents to help in the disposal of such wastes with no proper follow-ups. The improper disposal of such wastes is done mostly at the outskirts of the cities, or in the poor and rural villages. This is because of the high level of ignorance and illiteracy of the residents. This action often has its attending consequences (Adie and Osibanjo, 2009; Iwegbue *et al,* 2006; Chen *et al,* 2009; Oyediran and Aladejana, 2011).

2.2 Battery Components and Waste Products

Activities of the battery producing industry have a detrimental effect on the environment (Adie and Osibanjo, 2009). Some power generating batteries are produced from heavy metals, like Lead, Nickel, Cadmium, and Mercury, which can contaminate the environment, if the wastes produced alongside the batteries are not properly disposed (USEPA, 2005).

All batteries contain a corrosive liquid or semi-liquid electrolyte that is either a strong acid or a strong base. Lead acid batteries, produced as car batteries are made of lead plates; situated in a 'bath' of sulphuric acid (H_2SO_4) within a plastic casing (Department of the Environment and Heritage, 2005), while rechargeable batteries usually contain either potassium hydroxide and nickel or cadmium. Button batteries however, may contain mercury, cadmium and silver (enr.gov.nt.ca, 1998). Since batteries contain heavy metals, such as cadmium, lead, and lithium, they are generally

toxic and corrosive, due to the inability of the heavy metals in the waste to undergo biodegradation (enr.gov.nt.ca, 1998).

Consequently, there are hazards arising from improper handling and disposal of the wastes of batteries. Corrosive fluids can cause chemical burns and damage to a wide variety of materials. Metals in batteries, including lead, mercury and cadmium, are toxic and bio-accumulates in plants, as well as animals. They also persist in the environment through the release of corrosive fluids and dissolved metals into groundwater and the environment (enr.gov.nt.ca, 1998). These heavy metals could bioaccumulate within the biotic and abiotic components of the enviroment (Yusuf *et al*, 2003).

According to Environmental Compliance for Automotive Recyclers (2005), lead and sulphuric acid (H_2SO_4), components of the automobile battery, have the tendency to contaminate the air, soil, and water respectively. The Blacksmith Institute (2011) stated that about 6 million tons of lead is used annually on a worldwide basis and out of these, roughly three-quarters goes into the production of lead-acid batteries that are used in automobiles and other industries. Lead acid batteries are used in every countries of the world, and can be charged many times, but after numerous cycles of recharging, the lead plates eventually deteriorate. This causes the battery to lose its ability to retain stored energy for any period of time (Department of the Environment and Heritage, 2005). Once the Lead acid battery ceases to be effective, it is un-usable and deemed as Used Lead Acid Battery (ULAB). It is further classified as a hazardous waste under the Basel Convention (Basel Convention, 2010).

2.3 Environmental Consequences of Indiscriminate Open Waste-dump

Inadequate and or total concern for waste disposal system has given illegal waste managers the audacity to distribute hazardous wastes in locations where human residence is closely situated; thus, creating health hazards to those residents (Mfantseman Municipal Assembly, 2006). Between the late 1980s and 2000, Ori-Ile Olodo Community became an unapproved open waste site for the moribund lead acid battery manufacturing company, West African Battery industry (Oyediran and Aladejana, 2011; Adeagbo, 2011). The company's, waste contractors dumped the slag from the manufacturing site at Wofun-Olodo, which is about 5 km away in

undeveloped areas including Ori-Ile Olodo (Adie and Osibanjo, 2009). In actual fact, the wider Olodo community has several places spotted with traces of battery wastes (Adeagbo, 2011).

Similarly, the collection of waste batteries from end-users for the purpose of recycling them by poor individuals is a precarious venture (Blacksmith Institute, 2011). This is because these people lack the knowledge of the toxicity of battery components or the precautions to put in place in order to minimize their exposure to the batteries' toxic components (Blacksmith Institute, 2011). Throughout the informal recycling process, there are opportunities for exposure and most often the battery acid, which contains lead particulates, is haphazardly dumped on the ground, into waste pile, or into the nearest water body (Blacksmith Institute, 2011). Ori-Ile Olodo was said to be used for non-formal lead recovery operation using battery slag.

Slag from automobile battery manufacturing companies has been reported in Nigeria to contain lead concentrations ranging from 6% upwards (Basel Convention, 2004). Furthermore, as the lead plates are melted, lead ash falls into the surrounding environment, collects on clothing, or is directly inhaled by people in close proximity (Blacksmith Institute, 2011). In addition, soil containing lead compounds can turn to dust and become airborne, enabling the lead compounds to be easily inhaled or ingested in a variety of ways and children, when playing on the waste furnace slag and handling rocks or dirt containing lead, are often exposed to lead especially in their usual act of hand-to-mouth action (Blacksmith Institute, 2011).

They can also be exposed by bringing objects covered with lead dust back into the home (Blacksmith Institute, 2011). These make ingestion one of the most common routes of exposure for children, because lead dust often covers their clothing, food, soil and toys (Blacksmith Institute, 2011).

2.4 Effects of Exposure to Waste Battery Components

The intensive use of heavy metals, like lead, cadmium and others in industrial products increases their high occurrence in the waste generated. This is because all products will end up in waste at the end of their useful life span/cycle and they may not be attractive for recycling (Yahya, 1994; Udosen *et al*, 1990). Heavy metals may also be lost to

waste during manufacturing processes as well as use phases and such losses are often disposed of as manufacturing waste. These wastes usually increase soil heavy metal pollution (Udosen *et al*, 1990; Yahya, 1994; Benson, 2004; Zauyah *et al*, 2004). The general conclusion of these studies is that these metals are toxic and could result in serious health hazard along with environmental effects when exposure to them occurs.

Lead along with other pollutants generated during the production of batteries have cumulative serious health effects on both humans and their domestic animals (Blacksmith Institute, 2011). Environmental Compliance for Automotive Recyclers (2005) also stated that a continued exposure to lead in the environment can pose serious health hazard. Ignorance of the risks of lead contamination and a lack of viable economic alternatives has led to the systemic poisoning of many poor populations throughout the developing countries, Nigeria inclusive (Blacksmith Institute, 2011).

Lead contamination can also manifest its effects on agricultural farmlands and the various vegetations growing on it either by totally wiping off some important resident species, which may not be able to adapt to the potency of these toxic components, or by reduction of biological diversity of the survived species (Ononuga, 2005; Olusoga and Osibanjo, 2007). Resident soil organisms, such as, arthropods and annelids, which are of great economic and agricultural importance may as well be seriously affected. These may cause great loss to the trophic structure and the food web of any ecosystem (Campbell and Reece, 2005).

Much of the existing demand for lead is met through the recycling of Used Lead Acid Batteries, which is very effective in reducing the volumes of lead that is dumped into the environment; consequently, minimizing the efforts of mining more ores (Blacksmith Institute, 2011). However, in many places, much of the recycling is done on an informal, unhygienic and dangerous condition, which often times results in lead poisoning of the recyclers themselves and the neighboring communities (Blacksmith Institute, 2011).

So far, there is no known useful function of cadmium in biological organisms; but, it can pose a number of undesired properties that affect the environment as well as humans (Andreani *et al*, 2008). Similarly, there are many problems that may result from iron toxicity in humans (Litovitz and Manoguerra, 1992). Although iron is an

essential nutrient for plants, its accumulation within plant cells is toxic and plants respond to both iron deficiency and iron excess by inducing expression of different gene sets (Connolly and Guerinot, 2002). In essence, proper regulation of the disposal and recycling of generated battery wastes is mandatory for less waste associated effects and reduced health risks.

2.5 Heavy Metals Toxicity

Heavy metals are defined as those having a specific density of more than 5 g/cm3 and those that have main threats to human health (Järup 2003). Although adverse health effects of heavy metals have been known for a long time, exposure to them continues and is even increasing in some areas. Since the middle of the 19th century, production of heavy metals increased sharply for more than 100 years, with concomitant emissions to the environment through wide range of processes and pathways, including air, water, and soil (Järup 2003).

Moreover, many of the toxic effects of metals can be modified by concurrent exposure to other metals (Muhsin *et al,* 2010).The chemical form of the element influences the response, as it affects the biological availability. Trace metals alter enzyme activity by bonding to functional groups, deactivating them or binding metallic cations to them which stimulate their catalytic functions (Wright and Welbourn, 2009).

There are several heavy metals known to be carcinogens (Muhsin *et al,* 2010). In many exposed populations, some individuals are extra sensitive, while some are extra tolerant. However, children are more susceptible to lead exposures (Needleman *et al,* 1990). Also, some heavy metals are known to induce neuro-developmental toxicity in both animals and humans (Clarkson *et al,* 2003; Johansson *et al,* 2007). Accumulation of higher concentrations of these heavy metals predisposes animals to illness and cause alterations of immune system in diverse animals (Lapierre *et al,* 1999; Harper *et al,* 2007). A number of synchronous mechanisms are likely associated with heavy metals-induced neurotoxicity, including impairment of intracellular calcium homeostasis (Atchison, 2005), alteration of glutamate homeostasis (Aschner *et al,* 2000; Farina *et al,* 2003a; Soares *et al,* 2003) and oxidative stress (Franco *et al,* 2007; Manfroi *et al,* 2004). For the most part, the glutathione system, an antioxidant tool for protecting

cells against oxidative damage, represents a molecular target for some particular heavy metals (Stringari *et al*, 2008).

Most of the heavy metals bind to the sulfhydryl groups, thus inhibiting enzyme activity, disrupting cellular transport and causing changes in protein functions (Muhsin *et al*, 2010). The toxicity of heavy metals includes the blocking of functional groups of important molecules, e.g. enzymes, polynucleotides, transport systems for essential nutrients and ions, and substitution of essential ions from cellular sites (Muhsin *et al*, 2010).

Furthermore, heavy metals can bio-accumulate in different food webs, leading to elevated concentrations in higher trophic level feeders, such as, birds, among others (Scheuhammer *et al*, 2007). In highly contaminated areas, when these heavy metals are transferred from a mother bird to her eggs, impaired reproduction occurs in wild birds, such as, the common loon (*Gavia immer*), common tern (*Sterna hirundo*), and California clapper rail (*Rallus longirostris obsoletus*) (Heinz *et al*, 2008). Studies by Heinz *et al*, (2006) demonstrated the toxicity of methyl mercury (MeHg) to embryos of several bird species in various experimental conditions, using mainly different solvents, injection sites, and embryo ages.

Quite a number of researches showed that many industrial and agricultural processes contribute to the contamination of fresh water systems; thereby, causing adverse effects on aquatic biota and human health (Wang 2002; Dautremepuits *et al*, 2004). Heavy metals accumulate in the tissues of aquatic animals and exposure to chemicals is of public health concern to human beings (Kalay *et al*, 1999; Ashraf 2005; Muhsin *et al*, 2010). On the whole, the fact that heavy metals cannot be destroyed through biological degradation, coupled with their ability to accumulate in the environment, make the toxicants deleterious to the aquatic environment, and consequently to humans, who depend on aquatic products as sources of food.

2.5.1 Lead Toxicity

Lead is one of the most widely used metals in many industries, apart from battery industry (Yu *et al*, 2001); consequently, exposure to Pb continues to be a common problem all over the world, through food and water contamination, air pollution that is

caused by industrial emission and from fuel that contains Pb compounds (Muhsin *et al*, 2010). Environmental lead pollution mostly originates from lead containing battery, paints, gasoline, explosives and the disposal of municipal sewage sludge enriched in Pb (Chaney and Ryan, 1994; USEPA, 2006). Naturally, lead occurs in all soils in concentrations, ranging from 1 to 200 mg/kg, with a mean of 15 mg/kg (Chirenje *et al*, 2004). Apart from waste pollution incidences, the natural weathering processes, along with mining and smelting activities have resulted in lead contamination of the environment (Chirenje *et al*, 2004). Due to environmental ubiquity and persistence of Pb, its accumulation in organisms and biomass throughout the trophic chain suggests a continuous exposure (Muhsin *et al*, 2010).

Similarly, lead is known to be toxic to microorganisms, plants, animals and humans in the environment (European Commission, 2002). Also, excessive Pb exposure can cause seizures, mental retardation and behavioral disorders (Chirenje *et al*, 2004; Mench *et al*, 1994). This form of exposure usually results in acute lead poisoning. However, chronic poisoning from absorbing low amounts of lead over long periods of time is a much more pervasive problem (Ononuga, 2005; Adie and Osibanjo, 2009).

Furthermore, acute Pb poisoning results in mortality, while chronic exposure has indirect effects, such as, altering reproductive success, immune response, and physiology (Mazliah *et al*, 1989; Burger 1995; Burger and Gochfeld 2000b; Fair and Ricklefs 2002). The danger of lead is aggravated by low environmental mobility even under high precipitations (Chirenje *et al*, 2004; Mench *et al*, 1994; Callender and Rice, 2000).

Lead is not essential for plant and animal life. When it occurs in high concentration within the environment, it tends to induce different ecological and biochemical problems for both the environment and the biota (WHO, 1989a; WHO 1995). Lead can enter the body through the lungs or the mouth and can accumulate in the bones over long periods (Chirenje *et al*, 2004). According to Horsfall and Spiff (2004), lead is a heavy metal of great environmental concern and poses threat to plants, animal and human health due to its bio-accumulative tendency and toxicity. In fact, lead tends to accumulate in the food chain because of its persistent nature (Cossich *et al*, 2002).

Lead in blood is an indicator of new exposure, though determination of the blood Pb level alone cannot indicate the toxicity of Pb, since each individual has different degrees of tolerance of Pb (Marcus, 1985). Chronic exposure can be estimated when concentrations in accumulator tissue(s) are available (Muhsin *et al*, 2010). Although studies on dead animals provide useful information, ethical, legal, and scientific reasons indicate the need for other types of more easily available samples (feathers, eggs, excrements, regurgitated food, etc.), which will enable the estimation of exposure conditions (Burger and Gochfeld, 2000a; Dauwe *et al*, 2000).

In addition, since there has been no demonstrated biological need for Pb, its uptake and toxicity is likely mediated through imitating other cations (Ballatori, 2002). The most reasonable candidate is Ca^{2+}. There are strong evidences that Pb^{2+} acts as a Ca^{2+} antagonist (Busselberg *et al*, 1991; Rogers and Wood 2004). However, the identification of a specific ligand for Pb remains elusive. As in mammals, the principal effects of chronic Pb exposure in fish are presumably hematological (Hodson *et al*, 1978), neurological (Davis *et al*, 1976) and renal defects (Patel *et al*, 2006).

According to Harrison *et al*, (1993), lead also has toxic effects on the nervous system, kidney and liver. Health risks include impaired physical growth, kidney damage, retardation, and in extreme cases, even death (Harrison *et al*, 1993). Other studies examined reproduction and behavioral effects (Holcombe *et al*, 1976; Weber 1993; Shukla and Pai, 2005; Siddiqui *et al*, 2006; Basel Convention, 2010; Blacksmith Institute, 2011). Lead poisoning can lead to tiredness, headache, aching bones and muscles, forgetfulness, loss of appetite and sleep disturbance (Shukla and Pai, 2005). This is often followed by constipation and attacks of intense pain in the abdomen, called "lead colic" and the extreme cases of lead poisoning can cause convulsions, coma, delirium and possibly death (Blacksmith Institute, 2011). Exposure to Pb may also result in human breast lesions (Siddiqui *et al*, 2006). Women that are pregnant and become exposed to lead can have their fetus damaged with varying birth defects (Basel Convention, 2010).

In addition, lead has more negative impacts on children than adults and they suffer more permanent neurological damage (Basel Convention, 2010). Lead influences their nervous system, slowing down their nerve response, learning abilities and behavior (European Commission, 2002). Children that are exposed to lead right from their birth,

such as children in the embryonic stage, receive lead from their mothers through blood (Research Triangle Institute, 1999). Consequently, their exposure has been the main concern relative to the general populace. Their age and behavioral characteristics and bioavailability of lead in the source material influence their intake of lead (Research Triangle Institute, 1999). Baseline estimates of potential exposure of children to dusts, including intake due to normal hand-to-mouth activity, are 0.2 g/day for children 1-6 years old when both indoor and outdoor ingestion of soil and dust is considered, but for some children it may be up to 5 g/day (Research Triangle Institute, 1999).

Furthermore, in adult humans, approximately 10% of the dietary lead is absorbed, while in infants and young children, it is higher (European Commission, 2002). However, the absorption rates for lead from dusts/soils and paint chips can be lower, depending upon the bioavailability (USEPA, 2005). Similarly, depending upon the type of lead compounds, particle size, and solubility in body fluids, the absorption rate of inhaled lead compounds can be up to 50% (European Commission, 2002).

Absorbed lead is rapidly taken up into blood and soft tissue; followed by a slower redistribution to bone (European Commission, 2002). Lead absorption from the gastrointestinal tract ranges from 4% to70%, depending on the form of Pb ingested and the age of the exposed individual (European Commission, 2002). A large amount of lead is deposited into the bone, which acts as a depot, and a reliable indication of long-term exposure (Ferreira, 2011). According to Prasad and Freitas (2000), lead may accumulate in the human bones during much of the human lifespan. For this reason, the bone serves as an endogenous source of lead that may be released slowly over many years, after the exposure would have stopped (European Commission, 2002).

The effect of lead on the central nervous system of infants is of particular concern. Several studies show that the developing central nervous system (CNS) at prenatal and/or early postnatal periods is more susceptible to xenobiotic-induced neurotoxicity than in adults (Costa *et al*, 2004). Epidemiological studies suggest that low level exposure of the foetus and developing child may lead to repro-toxic effect that involves damage to their learning capacity and neuropsychological development (European Commission, 2002). Studies of children also indicate a correlation between higher lead contents in their blood and a lower Intelligence Quotient (IQ). Lead effects

on haemoglobin synthesis and anaemia in children have been found at lead blood levels above 40 g/dl (European Commission, 2002).

For the general populace, there is the slowing of nerve conduction velocity at low lead blood levels, and impairment of psychological and neurobehavioral functions after long-term lead exposure, in particular industrial workers (Goyer, 1986). Other biological effects of lead are inhibition of enzymes to the production of marked morphological changes and death, depending upon the level and duration of exposure (European Commission, 2002). Lead exposure is also associated with a small increase in blood pressure although there is no evidence to suggest that any association of lead blood levels with blood pressure is of major health importance (European Commission, 2002). Lead is known to cause kidney damage. Some of the effects are reversible, whereas chronic exposure to high Lead levels may result in continued decreased kidney function and possible renal failure. Renal failures occur among the general population when more sensitive indicators of function were measured (WHO, 1995). In addition, the reproductive effects of lead in the male are limited to sperm morphology and count whereas in the female, some adverse pregnancy outcomes have been attributed to lead.

However, lead does not appear to have deleterious effects on skin, muscle or the immune system (European Commission, 2002). WHO (1995) also indicated that the evidence for carcinogenicity of lead and several inorganic lead compounds in humans is inadequate. Lead, as well as some other heavy metals like Copper and Zinc are known to form important group of enzyme inhibitors when their normal concentrations are exceeded. These have been found to inhibit alkaline phosphate, catalase, xanthine oxidase and ribonuclease enzymes (Muhsin *et al*, 2010; Ononuga, 2005). Nonetheless, lead causes change in cell membrane permeability as well as reacts with sulphydryl groups and cations. It also has the affinity for reacting with phosphate groups and active groups of ATP or ADP (Jaiyeola, 1999).

In the environment, lead binds strongly to particles, such as, soil, sediment and sewage sludge and due to the low solubility of most of its salts, lead tends to precipitate out of complex solutions (European Commission, 2002). Soils contaminated with heavy metals usually lack long term or permanent cover. Barren soils are more prone to erosion and leaching which further spread pollutants in the environment (Salt *et al*,

1995). It has been found that the lack of vegetation cover allows further dispersal of lead as well as other heavy metals that are present in wastes disposed on soil, which increases human exposure indirectly (Ononuga, 2005). Furthermore, lead can accumulate in biota feeding primarily on particles, such as, worms and mussels which often possess special metal binding proteins; hence, have the removed metals from the general distribution into their organism (Prasad and Freitas, 2000).

The amount of lead within animals is closely associated with calcium metabolism. For example, lead concentrations in shellfish are higher in the calcium-rich shell than in the soft tissue, while in dolphins, lead is transferred from mothers to offspring during foetal development and breast-feeding (European Commission, 2002).One of the most important factors influencing the aquatic toxicity of lead is the free ionic concentration and the availability of lead to organisms. However, lead is unlikely to affect aquatic plants at the level it is in the general environment (European Commission, 2002).

In communities of aquatic invertebrates, some populations are more sensitive than others and community structure may be adversely affected by lead contamination. However, populations of invertebrates from polluted areas can show more tolerance to lead than those from non-polluted areas (European Commission, 2002).

Cationic form of lead (Pb^{2+}) is widely present in the environment as a trace metal (WHO, 1995). When bioavailable, Pb^{2+} can be highly toxic, since it can disrupt metabolic pathways, inhibiting key enzymes, such as aminolevulinate dehydratase (Rodrigues *et al*, 1989), carbonic anhydrase and Na^{+}–K^{+}-ATPase (Rogers *et al*, 2005), impairing Ca^{2+} uptake (Rogers and Wood, 2004) and causing iono-regulatory damage (Rogers *et al*, 2003). Moreover, Pb^{2+} has been described as a powerful neurotoxin for fish, since it can change neurotransmitter balance (Rademacher *et al*, 2001; Rademacher *et al*, 2003), reduce the activity of brain monoamine oxidase and acetyl cholinesterase (Katti and Sathyanesan, 1986), induce hyperactivity (Weber *et al*, 1991) and alter reproductive behavior (Weber, 1993; Alados and Weber, 1999).

In other aquatic invertebrates, adaptation to low oxygen conditions can be hindered by high lead concentrations (European Commission, 2002). Young stages of fish are more susceptible to lead than adults or eggs and typical symptoms of lead toxicity include spinal deformity and blackening of the tail region (European Commission, 2002).

Organic compounds are more toxic to fish than inorganic lead salts (European Commission, 2002).

The maximum acceptable toxicant limit for soluble species of inorganic lead ranges from 0.04 mg/litre to 0.198 mg/litre, depending on the species, and differences in conditions. There is evidence that frog and toad eggs are sensitive to nominal lead concentrations of less than 1.0 mg/litre in standing water and 0.04 mg/litre in flow-through systems; experience arrested development and delayed hatching (European Commission, 2002). For adult frogs, there are no significant effects below 5 mg/litre in aqueous solution, but lead in the diet at 10 mg/kg food has some biochemical effects (European Commission, 2002).

According to European Commission (2002), all species of experimental animals studied, including non-human primates indicated that lead causes adverse effects in several organs and organ systems, including the blood system, central nervous system, the kidney, and the reproductive and immune systems. Also, there are many reports of lead levels in wild mammals, but few reports of toxic effects of the metal in the wild or in non-laboratory species (European Commission, 2002).

In addition, even though motor impairment (Dietrich *et al*, 2005) cerebellar damage (Carvalho *et al*, 2007), and alterations in glutathione homeostasis (Stringari *et al*, 2008) have been described as important molecular mechanisms involved with Methyl mercury -induced neurotoxicity in rodents and primates, such indications of toxicity have not been examined in birds. Bertossi *et al* (2004) only showed that Methyl mercury induces neurotoxicity in chicks. Little is known about the molecular mechanisms related to heavy metals-induced neurotoxicity in chicks, among others.

Moreover, the tendency of inorganic lead to form highly insoluble salts and complexes in company of various anions, together with its tight binding to soils, drastically reduces its availability to terrestrial plants via the roots (IPCS, 1989). However, free lead is taken up by terrestrial plants through the roots and to a lesser extent through the shoots (WHO, 1989).

Translocation of the ion in plants is limited and most bound lead stays at root or leaf surfaces (European Commission, 2002). As a result, in most experimental studies on lead toxicity, high lead concentrations in the range of 100 to 1,000 mg/kg soil are

needed to cause visible toxic effects on photosynthesis, growth, or other parameters (European Commission, 2002). Thus, lead is only likely to affect plants at sites with very high environmental concentrations (European Commission, 2002).

In contaminated soils, lead may form secondary mineral elements like wulfenite ($PbMoO_4$), which is an orange, yellow or brown mineral, consisting of lead molybdate, and serves as a source of molybdenum or hydroxypyromorphite ($Pb_5(PO_4)_3OH$), among others (Pierzynski *et al*, 2000). Ingestion of lead-contaminated bacteria and fungi by nematodes leads to impaired reproduction (European Commission, 2002). Also, caterpillars that are maintained on a diet containing lead salts show symptoms of toxicity leading to impaired development and reproduction; but, the information available is too meager to quantify the risks to invertebrates during the decomposition of lead-contaminated litter (European Commission, 2002).

In addition, airborne lead may add significantly to occupational exposure and exposure of smokers, while in the general non-smoking adult population, the major exposure pathway is from food and water (Research Triangle Institute, 1999).

2.5.2 Cadmium Toxicity

Cadmium is released to the air, land, and water by human activities (WHO, 1992). In general, the two major sources of contamination are the production and consumption of cadmium and other non-ferrous metals as well as the disposal of wastes containing cadmium (WHO, 1992). The major route of exposure to cadmium for the non-smoking general population is via food since the contribution from other pathways to total uptake is small (WHO, 1992). Tobacco is an important source of cadmium uptake in smokers (WHO, 1992; ATSDR, 2008). In contaminated areas, cadmium exposure via food may be up to several hundred µg/day (WHO, 1992).

Increase in soil cadmium content results in an increase in the uptake of cadmium by plants and this makes the pathway of human exposure from agricultural crops vulnerable to increases in soil cadmium (WHO, 1992; European Commission, 2002). The uptake by plants from soil is greater at low soil pH. Processes that acidify soil, such as, acid rain may increase the average cadmium concentrations in foodstuffs (WHO, 1992). In most environmental conditions, cadmium enters first the roots;

consequently, the roots are likely to experience cadmium damage first (Sanita di Toppi and Gabrielli, 1999).

The primary source of exposure to cadmium is dietary for the general public; however, nutritional deficiencies can increase the risk of cadmium toxicity (ATSDR, 2008). Intake of cadmium is generally based on the diet, in particular corn and vegetables products (European Commission, 2002). Furthermore, a high fiber diet increases the dietary cadmium intake (Jarup *et al*, 1998).

Cadmium is a highly toxic and persistent environmental poison for micro-organisms, plants and animals (Sanita di Toppi and Gabbrielli, 1999; Barbier *et al*, 2005; ATSDR, 2008). Intake of cadmium contaminated food causes acute gastrointestinal effects, such as, vomiting and diarrhoea (Nordberg, 2004). Cadmium accumulates especially in the kidneys leading to kidney dysfunction with increased secretion of proteins in urine (proteinuri), for example, and other effects. The dominating effect for animals is kidney damage (Barbier *et al*, 2005; ATSDR, 2008), while cadmium is known to significantly influence leaf litter decomposition in micro-organisms (European Commission, 2002).

Cadmium interferes with many cellular functions mainly by complex formation with side groups of organic compounds, such as, proteins. This results in inhibition of essential activities (McGrath *et al*, 2001). Although the mechanisms of cytoplasmic toxicity are identical in all organisms, different plant species and varieties show a wide range of plasticity in cadmium tolerance. This reaches from high degree of sensitivity of most plants on the one hand to the hyper-accumulating phenotype of some tolerant higher plants on the other hand (McGrath *et al*, 2001).

Cadmium induces genetic and biochemical changes in plant metabolisms that are related to general and cadmium-specific stress responses (Blinda *et al*, 1997). On an expanded concentration scale, even sensitive species vary considerably in their response to cadmium (Malekzadeh *et al*, 2007). Cadmium tolerance is correlated with intracellular compartmentalization; hence, specific transport processes that allow the toxic effects of low cadmium levels to decrease at least (Brune and Dietz, 1995; Gonzalez *et al*, 1999).

Cadmium alters the glucose metabolism in mammals by intermediary metabolism being catalysed irreversibly; it affects the rate-limiting enzyme activity like that of glucose-6-phosphatase (Wright and Welbourn, 2009). The activation of the cellular antioxidant metabolism belongs to the general stress responses induced by heavy metals (Dietz *et al,* 1999). Data from experimental animals and humans have shown that pulmonary absorption is higher than gastrointestinal absorption. Depending on chemical speciation, particle size, and solubility in biological fluids, up to 50% of the inhaled cadmium compound may be absorbed (WHO, 1992). It has been reported that cadmium increases the activities of anti-oxidative enzymes, such as SOD (Rama Devi and Prasad, 1998), GPX (Karataglis *et al,* 1991) CAT and APX (Rama Devi and Prasad, 1998).

Cadmium was found to produce oxidative stress (Hendry *et al,* 1992; Somashekaraiah *et al,* 1992); but in contrast to other heavy metals, such as, copper, it does not seem act directly on the production of oxygen reactive species (Salin, 1988). The gastrointestinal absorption of cadmium is influenced by the type of diet and nutritional status, the nutritional iron status being of particular importance (WHO, 1992). The most important metabolic parameter for cadmium uptake is a person's possible lack of iron. People with low iron supplies showed a 6% higher uptake of cadmium than those with a balanced iron stock (Flanagan *et al,* 1978; Johannes *et al,* 2006). This is the main reason for the higher cadmium absorption in people with anaemia and habitual iron deficit, such as, children or menstruating women. Low iron blood levels stimulate the expression of DCT-1, a metal ion transporter in the GI tract, serving as a gate for cadmium absorption (Gunshin *et al,* 1997).

On an average, 5% of the total oral intake of cadmium is absorbed, but individual values range from less than 1% to more than 20%. There is a maternal-fetal gradient of cadmium. Although cadmium accumulates in the placenta, transfer to the fetus is low (WHO, 1992). Little research has been done on dermal absorption of cadmium. Wester *et al,* (1992) experimented on the absorption from cadmium-contaminated soil and water solutions by human cadaver skin in a diffusion cell-model. They could demonstrate a penetration of 8.8 % (soil) and 12.7% (water) of the applied cadmium dose into the skin; while the plasma uptake from soil was 0.01% and 0.07% from water (Wester *et al,* 1992). Lansdown and Sampson (1996) administered a cadmium

chloride solution to the shaved skin of rats daily for 10 days and the skin showed hyperkeratosis as well as acanthuses with occasional ulcerative change. It also showed an increase of the mitotic index of the skin cells (Lansdown and Sampson, 1996). Also, cadmium concentration in blood, liver and kidney increased; thus, indicating percutaneous absorption (Lansdown and Sampson, 1996).

Two mechanisms facilitate cadmium absorption by the skin: binding of a free cadmium ion to sulfhydryl radicals of cysteine in epidermal keratins, or an induction and complexing with metallothionein (Fasanya *et al*, 1998). The uptake through the human gastrointestinal is approximately 5% of an ingested amount of cadmium, depending on the exact dose and nutritional composition (Jin *et al*, 2002). Cadmium absorbed from the lungs or the gastrointestinal tract is mainly stored in the liver and kidneys, where more than half of the body burden is deposited (WHO, 1992).

With increasing exposure intensity, an increasing proportion of the absorbed cadmium is stored in the liver (WHO, 1992). Excretion is normally slow, and the biological half-time is very long in the muscles, kidneys, liver, and whole body of humans (WHO, 1992). The main organ for long-term cadmium accumulation is the kidney, and in it, the half-life period for cadmium is approximately 10 years (Orlowski and Piotrowski, 2003; Johannes *et al*, 2006). A life-long intake can therefore lead to a cadmium accumulation in the kidney, consequently resulting in tubulus cell necrosis (Johannes *et al*, 2006).

The cadmium concentrations in most tissues increase with age (WHO, 1992). Highest concentrations are generally found in the renal cortex, but excessive exposures may lead to higher concentrations in the liver (WHO, 1992). Several factors can increase this amount, such as low, intakes of vitamin D, calcium, and trace elements like zinc and copper (Johannes *et al*, 2006). Concerning zinc and calcium, it is assumed that their molecular homology could be a reason for compensatory higher cadmium absorption (Taylor, 1988).

Metallothionein is an important transport and storage protein for cadmium and other metals (WHO, 1992; Johannes *et al*, 2006). Once taken up by the blood, the majority of cadmium is transported bound to proteins, such as, Albumin and Metallothionein (Johannes *et al*, 2006). Cadmium can induce metallothionein synthesis in many organs

including the liver and kidney. The binding of intracellular cadmium to metallothionein in tissues protects against the toxicity of cadmium (WHO, 1992). Cadmium not bound to metallothionein may therefore play a role in the pathogenesis of cadmium-related tissue injury (WHO, 1992).

After consecutive hepatocyte necrosis and apoptosis, Cd-Metallothionein complexes are washed into sinusoidal blood. From here, parts of the absorbed cadmium enter the entero-hepatical cycle via secretion into the biliary tract in form of Cadmium-Glutathione conjugates (Johannes *et al,* 2006). Enzymatically degraded to cadmium-cysteine complexes in the biliary tree, cadmium re-enters the small intestines (Zalups, 2003).

Cadmium in blood occurs mainly in the red blood cells, and the plasma concentrations are very low (WHO, 1992). There are at least two compartments in blood, one related to recent exposure with a half-time of about 2-3 months, and one which is probably related to body burden with a half-time of several years (WHO, 1992). Thus, the blood concentration of cadmium serves as a reliable indicator for a recent exposition, while the urinary concentration reflects past exposure, body burden and renal accumulation (Jin *et al,* 2002). Excretion of cadmium takes place via faeces and urine (Johannes *et al*, 2006).

High inhalation exposures cause lethal pulmonary oedema. Single high-dose injection gives rise to testicular and non-ovulating ovarian necrosis, liver damage, and small vessel injury. Large oral doses damage the gastric and intestinal mucosa (WHO, 1992). Long-term inhalation exposure and intra-tracheal administration give rise to chronic inflammatory changes in the lungs (ATSDR, 2008), fibrosis, and appearances suggestive of emphysema (WHO, 1992). Long-term parenteral or oral administration produces effects primarily on the kidneys, but also on the liver and the haematopoietic, immune, skeletal, and cardiovascular systems. Skeletal effects and hypertension have been induced in certain species under defined conditions (WHO, 1992). Chronic cadmium exposure primarily affects the kidneys and secondarily the bones (ATSDR, 2008).

The occurrence of teratogenic effects and placental damage depends on the stage of gestation at which exposure occurs, and may involve interactive effects with zinc

(WHO, 1992). Piasek and Laskey (1999) evaluated the direct effects of in vitro cadmium exposure on steroidogenesis in rat ovaries. The most affected were productions of progesterone and testosterone (Piasek and Laskey, 1999). Low dosages of cadmium are reported to stimulate ovarian progesterone biosynthesis, while high dosages inhibit it (Henson and Chedrese, 2004). Maternal exposure to cadmium is associated with low birth weight and an increase of spontaneous abortion (Frery *et al,* 1993; Shiverick and Salafia, 1999). Some evidence exists also that cadmium is a potent non-steroidal estrogen in vivo and in vitro. Studies in rats showed that cadmium precipitates enhanced mammary development and increased uterine weight (Johnson *et al*, 2003).

Of greatest relevance to human exposure are the acute inhalation effects on the lung and the chronic effects on the kidney. Following long-term exposure, the kidney is the critical organ. The effects on the kidney are characterized by tubular dysfunction and tubular cell damage, although glomerular dysfunction may also occur (WHO, 1992). An increasing cadmium load in the kidney is also discussed to result in a higher calcium excretion; thus, leading to a higher risk of kidney stones (Johannes *et al,* 2006).

A consequence of renal tubular dysfunction is a disturbance of calcium and vitamin D metabolism. According to some studies, this has led to osteomalacia and/or osteoporosis, but these effects have not been confirmed by other studies (WHO, 1992). A direct effect of cadmium on bone mineralization cannot be excluded (WHO, 1992). Several studies have shown a connection between cadmium intoxication and bone damage, for example, workers exposed to cadmium-polluted fume and dust (Kazantzis 1979; Johannes *et al,* 2006). Further evidence for the causality of cadmium intoxication for bone maladies was found in 2003 by Honda *et al*. They described an inverse correlation of the STIFF index (an ultrasound method for measuring bone density) and urine cadmium concentration ((Honda *et al,* 2003; Johnson *et al,* 2003).

Similar findings were made within the OSCAR-Study, conducted with 1,021 people from southern Sweden. Individuals included in this study were either battery plant workers, or inhabitants of a town close to the battery plant, while a collection of unexposed people were included as reference group. The result showed a significant negative correlation between urine cadmium concentration and low bone mineral

density, especially in people of an age of 60 years and above. Furthermore, evidence for an increased risk of forearm fractures in cadmium-exposed individuals was found (Jarup *et al*, 1998). Even minimal environmental exposure to cadmium could cause skeletal de-mineralization (Straessen *et al*, 1999).

The toxic effects of cadmium in experimental animals are influenced by genetic and nutritional factors, interactions with other metals, particularly zinc, and pretreatment with cadmium, which may be related to the induction of metallothionein (WHO, 1992). There is some proof that cadmium can cause cancer. Waalkes *et al*, (1988) have shown that a subcutaneous injection of cadmium chloride can induce prostate cancer in Wistar rats. This group also postulated that high doses of cadmium can cause severe testicular necrosis in rat; followed by a higher incidence of testicular interstitial tumors. In contrast to laboratory data though, epidemiological studies could not convincingly prove cadmium to be a cause of prostate cancer (Sahmoun *et al*, 2005). An early publication, however, suggested an association of cadmium and renal cancer in humans (Kolonel, 1976).

Several methods are available for the determination of cadmium in biological materials and atomic absorption spectrometry is the most widely used (WHO, 1992). But, careful treatment of samples and correction for interference is needed for the analysis of samples with low cadmium concentrations and it is strongly recommended that analysis be accompanied by a quality assurance program (WHO, 1992).

2.5.3 Iron Toxicity

In nature, iron is usually found in its oxidized form, iron (III) oxide, which is insoluble. Ferrous iron (iron (II) oxide) is soluble and its toxicity varies, largely with the integrity of the gastrointestinal lining. In terms of blood values, iron levels above 350-500 µg/dL are considered toxic, and levels over 1000 µg/dL indicate severe iron poisoning (Falex, 2008). Iron is essential for many plant functions, some of which are chlorophyll development and function. It also plays a role in energy transfer within the plant and is a constituent of certain enzymes and proteins. It functions in plant respiration, plant metabolism and nitrogen fixation (Spectrum analytic, 2013).

Ongoing research and groundwater monitoring data from landfill sites indicate that iron contained in soils and aquifer media can be mobilized as a result of landfill construction and operation, a result of a process, known as reductive dissolution (Townsend, 2013). The toxicity of iron is governed by absorption and iron is absorbed in the ferrous state by cells of the intestinal mucous (British Nutrition Foundation, 1995). Gastric and intestinal secretions can reduce ferric ions, which are the unusable form of the iron, to the ferrous or absorbable state (Emery, 1991). Ferrous iron reacts with hydrogen peroxide to form hydroxide, thus generating the free radicals, which under normal conditions, are controlled and removed by antioxidants. But if there is an overabundance of iron in the body, the free radicals will not be removed fast enough and there will be a build-up (Lauffer, 1992).

The first indication of iron poisoning by ingestion is a pain in the stomach, as the stomach lining becomes ulcerated, and is accompanied by nausea and vomiting. The pain then abates for 24 hours as the iron passes deeper into the body resulting in metabolic acidosis, which in turn damages internal organs, particularly the brain and the liver. The body goes into shock and death from liver failure (Tenenbein, 2005). Iron toxicity is influenced by copper level, phosphorus level and vitamin E level, while the absorption of iron is enhanced by valine and histidine, ascorbic acids (with or without vitamin E), succinate, pyruvic acid and citric acid (British Nutrition Foundation, 1995).

Ferritin is a unique iron storage protein containing twenty four storage proteins and it is greatly abundant in the heart and liver. When excess dietary iron is absorbed, the body produces more ferritin; thus, causing its large amount to be in the heart and liver; and iron rushes there for storage (Lauffer, 1992). However, excess iron builds up in these organs and causes tissue destruction (Lag, 1993). Iron overload is characterized by increased levels of ferritin (the iron storage protein), haemosiderin (another storage protein), and iron catalyzed lipid peroxidation (CUDAS, 2013).

The iron accumulating disease is hemochromatosis and this result from the inability of the intestine to keep out unneeded iron (Emery, 1991). Iron accumulates in the liver causing siderosis, which is the accumulation of storage iron in tissues and damage to the storage organs (Lag, 1993). A normal man will usually absorb 1 mg of iron/day, but with this disease, he will absorb 3mg/day (CUDAS, 2013). As a result of iron

storage disease, the liver becomes cirrhotic and hepatoma; leading to primary cancer of the liver, which has become the most common cause of death among individuals with hemochromatosis (Emery, 1991). Also, when siderosis becomes severe in young people, myocardial disease is a common cause of death (Lag, 1993).

Among the problems that may result from iron toxicity are anorexia, oligura, diarrhea, hypothermia, diphasic shock, metabolic acidosis and death (Litovitz and Manoguerra, 1992). In addition to these, the individual may experience vascular congestion of the gastrointestinal tract, liver, kidneys, heart, brain, spleen, adrenals, and thymus (Lag, 1993). Impotence may occur in young men, and amenorrhea may occur in young women and both of these sexual related problems are due to iron loading in the anterior pituitary (Riederer and Youdim, 1993).

Iron toxicity is primarily pH related and occurs where the soil pH has dropped sufficiently to create an excess of available Iron. As with some other nutrients, the visible symptoms of Fe toxicity are likely to be a deficiency of another nutrient. Fe toxicity can also occur when Zinc is deficient, or the soil is in a "reduced" condition caused by very wet or flooded conditions. Excess Fe can result in Dark green foliage, stunted growth of tops and roots, dark brown to purple leaves on some plants (e.g. bronzing disease of rice) (Spectrum Analytic, 2013).

Iron is an essential nutrient for plants and it functions to accept, donate electrons as well as play important roles in the electron-transport chains of photosynthesis and respiration. But, iron is toxic when it accumulates to high levels and can act catalytically via the Fenton reaction to generate hydroxyl radicals, which can damage lipids, proteins and DNA (Connolly and Guerinot, 2002). Also, ferritin in plants plays an important role in iron homeostasis (Proudhon *et al*, 1996).

Studies of plant ferritins have revealed several important differences in the structure, localization and regulation of plant ferritins as compared to animal ferritins. For example, while animal ferritins are found in the cytosol, plant ferritins contain transit peptides for delivery to organelles called plastids (Proudhon *et al*, 1996). Moreover, while iron-regulated expression of animal ferritin is controlled mainly at the level of translation by a system of iron-responsive elements (IREs) and iron-regulatory RNA-binding proteins (IRPs) (Eisenstein, 2000), experiments in soybean and maize have

shown that iron regulates expression of plant ferritins both transcriptionally (Wei and Theil, 2000; Petit *et al*, 2001; Lescure *et al*, 1991; Lobreaux *et al*, 1992) and post-transcriptionally (Fobis-Loisy *et al*, 1996). Importantly, no IRE sequences have been identified in the regulatory regions of plant ferritin genes (Briat *et al*, 1999).

It is known that Fe (II) can interact with H_2O_2 to form hydroxyl radicals, so that using ferritin to store iron may protect cells against damage from oxidative stress. Thus, the expression patterns suggest that AtFer1 and AtFer3 play important roles in the protection of plant cells from oxidative stress resulting from iron overload (Petit *et al*, 2001). Previous studies have established a correlation between iron overload and production of abscisic acid (ABA) (Lobreaux *et al*, 1993).

2.6 Transfer of Toxic Waste Components along the Food Pyramid: Uptake, Bioaccumulation, Bioconcentration and Biomagnification

One of the key concepts in ecological studies is the idea that a disturbance in one area can lead to serious consequences elsewhere; thus, the interconnectedness of components in the environment makes it impossible for any event or phenomenon to be truly isolated (Smith, 2008). Non-degradable compounds, such as, some heavy metals can reach dangerous levels of accumulation as they are passed up the food chain into the bodies of progressively larger animals, which will accumulate even greater, and possibly life-threatening, concentrations of the compound (European Commission, 2002). Because humans are at the top of the food chain, they are particularly vulnerable to the effects of the non-degradable pollutants (Smith, 2008).

Moreover, because of the complex relationships among the many types of organisms and ecosystems, environmental contamination may have far-reaching consequences that are not immediately obvious or that are difficult to predict (European Commission, 2002). The buildup of toxins, particularly chemical pollutants in the tissues of individual organisms, poses a significant threat to the well-being of a functioning ecosystem (Smith, 2008).

The introduction of industrial and municipal solid waste into our environment has contributed greatly to the increase in levels of heavy metals in soil and vegetation grown on and around dumpsites. The soil and plants on these dumpsites constitute a

serious threat to the health of people living around such areas (Adefemi and Awokunmi, 2009). The dumpsite containing increased concentrations of toxic heavy metals may reach toxic levels through the food chain (Awokunmi *et al*, 2010).

Food chain is a linear series of organism dependent on each other for food. A set of interconnected food chains by which energy and materials circulate within an ecosystem is called food web (Adey, 1995; Orians, 1995; Naeem, 2001; USGS, 2010). Food webs make possible the transfer of energy from plants (the herbivores) to carnivores, omnivores, and ultimately to the detritivores as well as decomposers that enrich the soil with organic waste (Smith, 2008; Naeem, 2001). However, just as a food web can transfer materials essential to the life of organisms, it is also a devastatingly efficient conduit for the transfer of poisons (Chapman, 1999).

The food web is divided into two broad categories, which are the grazing web that typically begins with green plants, algae, or photosynthesizing plankton, and the detrital web, which begins with organic debris. In a grazing web, materials typically pass from plants to plant eaters or herbivores and also to flesh eaters or carnivores, while in a detrital web, materials pass from plant and animal matter to bacteria and fungi or decomposers, then to detrital feeders or detritivores, and then to their predators or carnivores (Smith, 2008).

Energy flow fuels the nutrient cycles, which begins with nutrients released from organic matter by weathering and decomposition in a form that can be picked up by plants (European Commission, 2002). Plants incorporate nutrients available in soil as well as water and store them in their tissues and from these, the nutrients are transferred from one trophic level to another through the food web (European Commission, 2002). If inputs of any element greatly exceed outputs, the nutrient cycle in the ecosystem becomes stressed or overloaded, resulting in pollution (Smith, 2008). Thus, pollution can be considered an input of either nutrients or undesirable chemical elements exceeding the capability of the ecosystem to process them (European Commission, 2002).

Nutrients eroded and leached from agricultural lands, along with sewage and industrial wastes accumulated from urban areas, all contribute to either aquatic or terrestrial pollution. They destroy plants and animals that cannot tolerate their presence or the

changed environmental conditions caused by them (European Commission, 2002). At the same time, they favor a few organisms more tolerant to changed conditions (European Commission, 2002). These actions are due to the fact that certain organisms cannot easily process them, while others can, either by incorporating them into the metabolic system or by excreting them through urine or other substances produced by the body (Smith, 2008). Often times, the only way for the organism to release toxins is by passing them on to other members of the food web and because organisms at each successive trophic level must consume more biomass to meet their energy requirements, they experience an increase in contamination (European Commission, 2002).

Pollution can also alter the metabolism of microorganisms and arthropods in a given soil environment. This may destroy some layers of the primary food chain, and thus have a negative effect on predator animal species (Smith, 2008). Also, small life forms may consume harmful chemicals, which may then be passed up the food chain to larger animals; this may lead to increased mortality rates and even animal extinction (European Commission, 2002).

Terrestrial and aquatic plants may absorb pollutants and pass them up the food chain to consumer animals and humans (Pichtel *et al*, 2000). Also, plants may absorb soil contaminants and pass them up the food chain (Taylor and Percival, 2001). However, in stabilizing metal-contaminated sites, a lower metal concentration in shoots is preferred in order to prevent metal potentially entering the ecosystem through the food chain (Pichtel *et al*, 2000; Taylor and Percival, 2001; Yang *et al*, 2003).

Humans themselves can serve as repositories for contaminants and this makes a mother nursing her baby of particular concern (Basel Convention, 2010). Assuming the mother's own system has been contaminated by toxins, it is likely that her milk contains traces of the harmful chemical, which will be passed on to her child and this is a very serious matter (USEPA, 2003).

2.6.1 Uptake or Absorption of Toxic Waste Components

Generally, plants provide mineral nutrition and trace elements along with chemicals of medicinal value to man and other animals. Their living bodies require these minerals and trace elements as chemical elements for numerous biological and physiological processes, necessary for the maintenance of health (Hendler and Sheldon, 1990). Minerals include compounds of the elements like calcium, magnesium, phosphorus, sodium, potassium, sulfur and chlorine, while trace elements are iron, iodine, copper, manganese, zinc, molybdenum, selenium, and chromium (Hendler and Sheldon, 1990). When present at high concentrations, even micro-nutrients and non-essential metals, like lead are toxic (Rozman and Klaassen, 2001); and organisms expend energy to regulate the internal concentrations of these metals (Epstein, 1972).

Plant and animal communities in mineral-rich areas differ from those in surrounding areas in relation to soil types (Lawrence *et al*, 2004). Regulation of absorption of toxic metals may occur at the point of uptake across an external membrane or altogether internally. Metals may be sequestered into inactive granules, bound to organic molecules, like phytochelatins in plants or metallothioneins in animals, or shunted into vacuoles away from active enzyme areas. Consequently, in many situations, metals bio-accumulate (U.S.EPA, 2002a). The concept that many metals are required for organism health at one range of concentrations and are toxic in quantities that may be either more or less than that range has been referred to as the "window of essentiality" (Hopkin, 1989), or the "optimal concentration range" for essential elements (Alloway, 1995; Fairbrother and Kapustka, 1997; Van Assche *et al*, 1997).

Furthermore, there are studies about the response of crop species to heavy metals and these studies report mechanisms that are responsible for their tolerance or sensitivity (Chatterjee and Chatterjee, 2000; Ernst 1996; Lindon and Henriques 1992; Mullar *et al*, 2000). Avoidance of metal uptake or its accumulation in plant tissues without developing any toxicity symptoms is considered as metal tolerance in plants. Sensitive species may lack this mechanism and show toxicity symptoms and poor development (Mahmood *et al*, 2005).

Plants can thrive in soil contaminated to levels that are often orders of magnitude higher than current regulatory limits, which are often set relatively independent of

plant tolerance limits and are most often derived from human health and aquatic toxicology end points (Cunningham and Ow, 1996). Jaiyeola (1999) noted that the exchangeable heavy metals (Fe, Pb etc.), are found in minor fractions of the total metal concentration of the soil. This shows that metals found in the exchangeable fraction are highly immobile and they are therefore phyto-available (Jaiyeola, 1999).

Plants have evolved a great diversity of genetic adaptations to handle potentially toxic levels of metals and other pollutants that occur in the environment (Goldsbrough *et al*, 1995). In plants, uptake of metals occurs primarily through the root system, in which the majority of mechanisms to prevent metal toxicity are found (Goldsbrough *et al*, 1995). Also, plants use a variety of methods to reduce their susceptibility to metal toxicity. In some species, uptake of poisonous metals is greatly reduced, while in other species, the elements are taken into the plants, but mainly remain in the roots (Salisbury and Ross, 1985).

For plants, three (3) patterns reflecting different metal tolerance mechanisms have been recognized, which are accumulators (in which metals are concentrated in above ground plant parts from low or high soil levels); the indicators (in which metal concentrations in shoots are approximately equal to soil concentrations) and the excluders (in which metal concentrations in shoots are maintained at constant and low levels over a wide range of soil concentrations) (Baker, 1981). At high levels of metal bioavailability, loss of the capacity to restrict metal uptake can lead to phyto-toxicity in excluders, while phyto-toxicity can occur in accumulators and indicators as physiological homeostatic systems become overwhelmed by the internal concentrations of metals (Baker, 1981).

According to European Commission (2002), toxicity occurs at the point where the capacity of an organism to regulate the internal concentration of metals is lost, resulting in a loss of functions required for normal growth or to sustain life. Generally, this occurs at one or more internal cellular locations or may affect an entire organ. However, for plants, toxicity may also occur at the root surface without the substance ever entering the internal portions of the plant (European Commission, 2002). Phyto-remediation takes advantage of plants nutrient utilization processes to take in water and nutrients through roots, transpire water through leaves, and act as a transformation system to metabolize organic compounds.

2.6.2 Bio-accumulation of Toxic Waste Components

Bio-accumulation is the process whereby toxic substances that gain entrance into the body of an organism are stored in the body tissue and it happens in two ways: bio-concentration and bio-magnification (Chapman, 1999). Because many metals are essential for proper biological function, organisms are able to metabolize; thus, regulate both essential and non-essential metals within their internal systems (Chris *et al*, 2012). Regulation of metal accumulation by organisms complicates the interpretation and application of bioaccumulation data for aquatic and terrestrial organisms; thus, organisms have evolved homeostatic mechanisms that allow metals, as naturally occurring substances, to be stored in non-available forms (U.S.EPA, 2002d). These mechanisms regulate the uptake and excretion of metals to maintain tissue concentrations within desirable range, as well as to prevent toxicity (U.S.EPA, 2002d; Fairbrother and Kapustka, 1997; Chapman and Wang, undated).

For certain elements, bioaccumulation is required for organism' health and normal function, like for essential trace elements, such as, copper and zinc (Kern *et al*, 2000). But in other situations, bioaccumulation produces residues in plants and animals that cause direct toxicity to the exposed organism or indirect toxicity to consumers (Kern *et al*, 2000). Furthermore, the metabolism of an essential element can affect the metabolism of a non-essential toxic metal, as in the case of calcium and lead in the central nervous system (Kern *et al*, 2000).

Hyper-accumulation is a natural ability of some plant species that grow on naturally metal-rich areas of the earth, to take up huge amounts of metals (Chaney *et al*, 1994). Hyper-accumulators are conventionally defined as species capable of accumulating metals at levels 100-fold greater than those typically measured in common non-accumulator plants (Reeves and Baker, 1999). Almost all metal-hyper-accumulating species known today were discovered on metal-rich soils, either natural or artificial, often growing in communities with metal excluders (Raskin *et al*, 1994; Baker 1995). Actually, hyper-accumulation is an important eco-physiological adaptation to metal stress and one of the manifestations of resistance to metals (Baker and Brooks 1989). Alternately, they may absorb and bio-accumulates toxic trace elements, including heavy metals (Raskin *et al*, 1994).

In general, heavy metals are persistent pollutants, which once introduced into the environment, are not readily converted into harmless products (Muhsin *et al*, 2010). They are often accumulated in the tissues of organisms, which having taken them up, cannot excrete them; thus, leading to an amplification of their concentration in animals higher up in the food chain (Chapman, 1999). According to Elizabeth (2005), plants can take up pollutants from a polluted site, which may be stabilized or degraded in the rhizosphere; sequestered inside the plant tissue; or volatilized. Humans as omnivores at the top of many food chains are, therefore, exposed to the risk of taking a diet enriched by toxic metals (Bryce-Smith, 1972; Ononuga, 2005).

Bradshaw (1952) found that plants of the grass *Agrotis tenuis* that grew on the waste by old lead mines in Wales evolved the ability to tolerate the high levels of lead in the waste. Since then, such tolerant ecotypes have been found in a number of other species, mostly grasses (Chapman and Reiss, 1999). In previous studies carried out by Ononuga (2005) on Ori-Ile waste-dump, corn grass tended to have the highest lead concentration in its tissue. Previous studies also have shown that Vetiver grass can grow well in soils contaminated with multiple elements at high concentrations such as those found at coal, cadmium, and gold mining sites (Truong and Baker, 1998; Roongtanakiat and Chairoj, 2002) and can also accumulate relatively high concentrations of lead (Chantachon *et al*, 2004).

Consequently, plants dominate the structure of polluted communities, and indicator plants, like grasses have been used extensively in ecological studies, due to the fact that they are much easier to sample and analyze than animals. However, metals only reach parts of the plant and then accumulate in the cell walls (Salisbury and Ross, 1985). In the cell wall, the metal is bound to a stable complex with either a pectin-like or proteinaceous substance (Bradshaw and McNeilly, 1981).

Plants with high tendency of heavy metal accumulation are often classed as being suitable for phyto-remediation and possess certain characteristics, like tolerance to the prevailing contaminant, a high-biomass production (fast growth with large biomass), ease of handling and established cultural practices (phenotype suitable for easy harvest, treatment and disposal), and should preferably be indigenous to the region (Ensley, 2000; Vangronsveld and Cunningham, 1998). For example, edible corn has

been known as hyper-accumulator of certain heavy metals and is therefore branded as ideal for remediation purposes.

There is the potential for significant hazard to grazing vertebrates, which persists for systemic toxicants, like lead that bio-accumulate in plants to highly potent level. However, it is suspected that the toxicants incorporated into plants are less easily perceived during feeding and are therefore potentially more hazardous than contact poisons (Viswanathan and Misra, 1989). There appears to be a negative correlation between body size and metal bioaccumulation (Newman and Heagler, 1991).

2.6.3 Bio-concentration of Toxic Waste Components

Bio-concentration is the uptake of toxic substances from the environment, which may be either by active uptake (metabolically controlled) or passive uptake (Haslam, 1990). The toxic substance cannot be excreted from the organism's body; thus, remain in the body in an unchanged state as conservative materials. When animals consume a diet so enriched, it could cause them to have an even greater body-burden of the toxic substance if they also bioaccumulations or excrete at a slow rate (Clarke, 1992). This is highly significant in top predators because the quantity keeps increasing as they consume more bio-accumulators (Clarke, 1992).

At low concentrations, where organisms experience nutritional deficiency, greater uptake and retention of metals occur to meet nutritional requirements and at concentrations above the nutritional requirement, homeostasis maintains a concentration limit in the organism. However, beyond that range, homeostatic mechanisms (such as regulation by excretion) can become overwhelmed, resulting in toxicity (Fairbrother and Kapustka, 1997).

For this reason, homeostasis should be considered in ecological risk assessment for metals, as it influences or regulates Bioconcentration Factors (BcFs), Bioaccumulation Factors (BaFs), and exposure concentration (Fairbrother and Kapustka, 1997; U.S.EPA, 1985a; Spacie and Hamelink, 1985). The BcFs or BaFs could decrease with an increase in exposure concentration (U.S. EPA, 2002a; Adams *et al*, 2000). According to Salt *et al* (1995), the plant's root system provides an enormous surface area that absorbs and accumulates the water and nutrients essential for growth. In

many ways, living plants can be compared to solar-powered pumps that can extract and concentrate certain elements from the environment (Salt *et al*, 1995).

The site of toxic action could be an enzyme, a membrane, or a co-factor critical to some biochemical pathway, but often, multiple sites of action for a particular substance might exist, and toxicity could be manifested in different ways, depending on how the primary modes of action and the cascade of secondary effects are linked (Muhsin *et al*, 2010). For many toxicity endpoints, multiple disruptions of biochemical functions are likely to occur (European Commission, 2002).

Toxicity thresholds refer to concentrations above which organisms exhibit adverse effects and data from a single experiment or from several studies (either laboratory or field observations) are used to identify thresholds (Muhsin *et al*, 2010). Metallothioneins (MT) and phytochelatins are small proteins in animals and plants respectively, which regulate as well as detoxify many metals within the organism and this mechanism of regulation is very effective when the organism is exposed to background or even moderately elevated levels of many metals (Sneller *et al*, 2000).

The regulation of metals within the organism has limits, however, and plants have demonstrated that the interactive effects of cadmium and arsenate were concentration-dependent and ranged from non-additive to synergistic, as concentrations increased (Sneller *et al*, 2000). At high concentrations, the ability of the plant to regulate metals collapsed and phytochelatin levels dropped (Sneller *et al*, 2000). The formation of metal granules has been demonstrated in invertebrates as an alternative protective mechanism (Rainbow and White, 1989; Vogt and Quinitio, 1994; Walker, 1977).

The bio-concentration of metals varies greatly with the species of organism, exposure concentration, environmental factors, and the specific metal (Memmert, 1987). Some species accumulate metals to high levels, while others closely regulate interval concentrations or sequester the metal with cellular binding protein (Rainbow *et al*, 1990). Species variation in bio-concentration may result from differences in the size, rather than the species or lipid content of an organism (Davies and Dobbs, 1984). Effects of environmental conditions on bio-concentration, for example temperature can be dramatic (Barron, 1990). Other environmental parameters, like pH, salinity and

dissolved oxygen can affect bio-concentration (McKim and Erickson, 1991). Size of organism can also influence metal bio-concentration (Newman and Heagler, 1991).

2.6.4 Bio-magnification of Toxic Waste Components

Bio-magnification is peculiar to animals as it occurs through the food chain and it is the process where organism, which are higher up in the food chain accumulate toxic substances to concentrations much higher than those occurring in the water or particulate material; hence, toxins become more concentrated with each link in a food chain (Chapman, 1999). It results from biomass at each trophic level being produced from a much larger biomass ingested from the level below (Chapman, 1999).

Apart from the acute effect as well as long term effect of ecological poisons in the environment, many of the toxic residues get accumulated in all species. Numerous succumb to toxicity beyond threshold levels; but, many exist as symptomless cases. These species, when consumed by predators, also pass on their toxicants. This way, as the food ladder goes up, higher levels of toxicants are accumulated. This phenomenon, known as bio-magnification, along with the process of bio-concentration by individual species as a result of direct uptake, poses health risks to human food items. Thus, vital species can be adversely affected; resulting in food shortage or they can pass on the toxic residues to humans (Ononuga, 2005).

In addition to direct exposures from environmental compartments (plus their effects and indirect exposures and impacts through the food chain) bio-magnification of xenobiotic residue also forms a major part of ecological risk assessment (Chapman and Reiss, 1999). Significant bio-magnification for metals in higher vertebrates appears to occur only for hydrophobic alkyl metals, because metals are internally regulated by higher organisms (Bryan and Langston, 1992).

Environmental quality influences human health risk patterns and this may be due to pathogenic factors multiplying and spreading in the environment or ecological magnification of toxicants in food (WHO, 2009). It may also result from direct exposure to hazardous substances from air, water and food (WHO, 2009). The degree and magnitude of the influence on the quality of the environment, the nature of the risk factors, and the relative susceptibility or resistance of the population could vary

considerably (WHO, 2009). Even though the individual influences of several environmental pollutants on specific health problems of the community have been fairly well understood, the situation regarding multiple risk factors is not clear (WHO, 2009).

2.7 Soil as a Point Source of Pollution

Soils, whether in urban or agricultural areas, represent a major sink for heavy metals released into the environment from a variety of anthropogenic sources (Arendt *et al*, 1990; Nriagu, 1991). Once in soil, some of these metals would be persistent because of their fairly immobile nature, while other mobile metals have the potential of transfer either through the soil profile down to the groundwater aquifer or absorbed via plant-root. Consequently, they could serve as a source of threat to the food chain (Mench *et al*, 1994). The occurrence of this phenomenon is correlated with the degree of industrialization and intensity of chemical usage.

Generally, soil contamination results when hazardous substances are either spilled, buried directly in the soil or migrate to the soil from a spill that has occurred elsewhere. Another source of soil contamination could be water that washes contamination from an area containing hazardous substances and deposits, such in the soil as it flows over or through it. The concern over soil contamination stems primarily from health risks. The extent of contaminated land has not been fully addressed by developing countries, such as, Nigeria that probably have the next generation of new soil contamination cases (USEPA, 2006). Soil contamination may affect people, who live on it, plants that put roots into it, and animals that move over it.

Some of the more common soil contaminants are heavy metals, such as, lead, chromium, and cadmium; others include chlorinated hydrocarbons (CFH), MTBE, zinc, arsenic and benzene. The heavy metals are a category of very toxic and dangerous pollutants in the environment and their toxicity occurs when they occur in super-abundance within the environment (Chapman and Reiss, 1995). Soil heavy metal contamination is a serious source of problem to either the food chain or food web. This is because, in contaminated soils, heavy metals may form secondary mineral elements, which could be absorbed by plants; thus, constitute toxic metabolites in many herbivores and omnivores along the food chain (Pierzynski *et al*, 2000). Few soils are

completely bare of vegetation solely because of the toxicity of the inorganic ions they contain (Macnair *et al*, 1993; Lawrence *et al*, 2004).

2.8 Water Contamination arising from Soil Pollution

Water is an essential need of any living system and is a self-restoring system that occurs in different forms that are beneficial to man. Water can be used for drinking, cooking, washing, irrigation, aquaculture, among other uses. Living organisms require water that is moderately pure. In spite of this, water pollution has become one of the most critical environmental problems of the century and may come from two sources. Chemical contaminants, which enter surface and underground waters, can be classified according to the nature of their sources, as either point pollution or non-point pollution. Point sources discharge pollutants from specific locations, such as, factories, sewage treatment plants, and oil tankers and can be technologically monitored (Zimmerman, 2008).

Pollution from nonpoint sources occurs when rainfall or snowmelt moves over and through the ground. As the runoff moves, it picks up and carries away pollutants, such as, pesticides and fertilizers; depositing the pollutants into lakes, rivers, wetlands, coastal waters, and even underground sources of drinking water. Pollution arising from nonpoint sources accounts for a majority of the contaminants in streams and lakes. Point pollution involves pollution from a single concentrated source that can be identified, while non-point pollution involves pollution from dispersed sources that cannot be precisely identified. Water contamination usually affects the streams, lakes, underground water, bays and oceans. These result mostly from industrial wastes, sewages and use of agricultural chemicals such as fertilizers and pesticides (Zimmerman, 2008).

In developing nations, more than 95 percent of urban sewage is discharged untreated into rivers and bays, creating a major human health hazard. Industrial pollutants that run into streams, rivers, or lakes can have serious effects on wildlife, plants, and humans as well. Water runoff also carries fertilizing chemicals such as phosphates and nitrates from agricultural fields and yards into lakes, streams, and rivers. These combine with the phosphates and nitrates from sewage to speed the growth of algae. Thus, the water body may become choked with decaying algae, which severely

depletes the oxygen supply. This process, called eutrophication, can cause the death of fish and other aquatic life (Engelking, 2008).

Erosion, the wearing off of topsoil by wind and rain, also contributes to water pollution. Soil and silt washed from logged hillsides, plowed fields, or construction sites can clog waterways and kill aquatic vegetation. Even small amounts of silt can eliminate desirable fish species. Heavy metals, such as lead, mercury and selenium, get into water from many sources, including even natural soil. Like pesticides, heavy metals become more concentrated as animals feed on plants and are consumed in turn by other animals. When they reach high levels in the body, heavy metals can be immediately poisonous, or can result in long-term health problems similar to those caused by pesticides and herbicides (Engelking, 2008).

Cities and other residential communities contribute mostly sewage, with traces of household chemicals mixed in. Sometimes industries discharge pollutants into city sewers, increasing the variety of pollutants in municipal areas. Pollutants from agricultural sources, such as, farms, pastures, feedlots, and ranches contribute animal wastes, agricultural chemicals and sediment from erosion.

The oceans, vast as they are, are not invulnerable to pollution. Pollutants reach the sea from adjacent shorelines, from ships, and from offshore oil platforms. Sewage and food waste discarded from ships on the open sea do little harm, but plastics thrown overboard can kill birds or marine animals by entangling them, choking them, or blocking their digestive tracts if swallowed. Oil spills often occur through accidents. Routine and deliberate discharges, when tanks are flushed out with seawater, also add a lot of oil to the oceans. Offshore oil platforms also produce spills. The largest oil spill ever was the result of an act of war. An oil spill has its worst effects when the oil slick encounters a shoreline. Oil in coastal waters kills tide pool life and harms birds and marine mammals by causing feathers and fur to lose their natural waterproof quality, which causes the animals to drown or die of cold. Additionally, these animals can become sick or poisoned when they swallow the oil while preening (grooming their feathers or fur).

Water that collects beneath the ground is called groundwater. Worldwide, groundwater is 40 times more abundant than fresh water in streams and lakes. Groundwater is a

renewable resource whose reserves replenish relatively slowly. Groundwater contamination arises from leaking underground storage tanks, poorly designed industrial waste ponds, and seepage from the deep-well injection of hazardous wastes into underground geologic formations. By some estimates, on average, 25% of usable groundwater is contaminated, and in some areas as much as 75% is contaminated (Zimmerman, 2008).

Surface water is another basic category that water supply falls into and is the water that exists in streams, rivers, or lakes. It occurs as a tributary or a stream, river or glacier that joins a larger stream, river or glacier or a lake (Jackson, 2008). Surface water can be polluted by wastes that are washed into them from a nearby waste-dump. Heavy metals get into water from many sources, such as, polluted land areas (Redmond, 2008). Water runoff, a nonpoint source of pollution, carries toxic pollutants from land areas into lakes, streams, and rivers, which causes serious deleterious effects on the aquatic life (Engelking, 2008). Similarly, erosion whether wind or water, can contribute significantly to water pollution by being a source of heavy metal introduction into aquatic bodies. Apart from this, the fine soil sediments could also clog waterways and kill aquatic vegetation or clog fish gills and thus lead to their death (Engelking, 2008).

Water pollution can also be caused by other types of pollution. The acid rain can be carried into a stream or lake, becoming a form of water pollution that can harm or even eliminate wildlife. Similarly, the garbage in a landfill can create water pollution, if rainwater percolating through the garbage absorbs toxins before it sinks into the soil and contaminates the underlying groundwater. Pollution may reach natural waters at spots we can easily identify, known as point sources, such as waste pipes or mine shafts. Non-point sources are more difficult to recognize. Pollutants from these sources may appear a little at a time from large areas, carried along by rainfall or snowmelt. For instance, the small oil leaks from automobiles that produce discolored spots on the asphalt of parking lots become nonpoint sources of water pollution when rain carries the oil into local waters. Most agricultural pollution is non-point since it typically originates from many fields (Hart, 2009).

2.9 Maize: Physiological Adaptation and Economic Importance

Maize or corn has been enlisted as one of the world's four (4) top crops, namely maize, rice, wheat and barley. These produce more tonnage than the next 25 crops combined and human well-being depends on these few grasses (cereals) that even small crop failures of any one of them can produce widespread hunger and economic disruption.

Maize is the common name for the cereal grass widely grown for food and livestock fodder. Maize ranks with wheat as well as rice as one of the world's chief grain crops and ranks third in the global cereal production. Maize is utilized as food, feed and fodder, while its large quantities are used in extracting oil, manufacturing cellulose products, and mild abrasives.

Maize is classified as *Zea mays* and the maize plant has an erect, solid stem, rather than the hollow one of most other grasses. It varies widely in height: some dwarf varieties being little more than 60 cm (2ft) at maturity, whereas other types may reach heights of 6 m (20ft) or more. The average height of maize is 2.4 m (8ft).

The leaves, which grow alternately, are long and narrow. The main stalk terminates in a staminate (male) inflorescence, or tassel. The tassel is made up of many small flowers termed spikelets, and each spikelet bears three small anthers, which produce the pollen grains, or male gametes. The pistillate (female) inflorescence or ear is a unique structure with up to 1,000 seeds borne on a hard core called the cob.

The ear is enclosed in modified leaves called husks. The individual silk fibers that protrude from the tip of the ear are the elongated styles, each attached to an individual ovary. Pollen from the tassels is carried by the wind and falls onto the silks, where it germinates and grows down through the silk until it reaches the ovary. Each fertilized ovary grows and develops into a kernel.

The many varieties of maize show widely differing characteristics. Some varieties mature in 2 months; others take as long as 11 months. The foliage varies in intensity of color from light to dark green, and it may be modified by brown, red, or purple pigments. Mature ears vary in length from less than 7.5 cm (3 in) to as much as 50 cm (20 in). The number of rows of kernels ranged from 8 to 36 or more. Six general groups of varieties are differentiated by the characteristics of the kernel.

The most important advance in the cultivation of maize was the introduction of hybrids. Botanists have developed thousands of hybrids, of which one or more can flourish in almost any combination of soil and climate found in the farming areas. Hybrids have also been developed to increase maize yields in many other areas of the world.

Maize is an important food staple and animal feed. It is an excellent source of carbohydrates, but since it is low in total protein and the protein is of poor quality, a maize diet must be supplemented with proteinaceous foods for satisfactory growth. Approximately three-fifths of the maize sold by farmers in the United States is used as livestock feed. About half of that amount is fed directly to hogs, cattle, and poultry, and the rest is used in mixed feeds. Another one-fifth of U.S. maize is exported; the remaining one-fifth is sold as food and taken by commercial users for the production of alcohol and distilled spirits, syrups, sugar, maize-starch, and dry-process foods.

Maize-cobs are an important source of furfural, a liquid used in manufacturing nylon fibers and phenol-formaldehyde plastics, refining wood resin, making lubricating oils from petroleum, and purifying butadiene in the production of synthetic rubber. Ground maize-cobs are used as a soft-grit abrasive. Large, whole cobs from a special type of maize, "cob pipe" maize, are used for pipes for smoking tobacco.

Maize oil, extracted from the germ of the maize kernel, is used as a cooking and salad oil and, in solidified form, as margarine; it is also used in the manufacture of paints, soaps, and linoleum. The search for alternate sources of energy has brought attention to maize as a fuel source. High in sugar content, maize is processed to produce alcohol for use with gasoline as gasohol, and the dry stalk is a potentially important fuel biomass.

Many researchers have investigated the uptake and accumulation of lead and cadmium in different plant species. In fact, the uptake, metabolism and negative effects of heavy metals on maize have been documented in literature (Aliu *et al*, 2013). According to Aliu *et al*. (2013), the exposure of maize seedlings to lead, cadmium and mercury resulted in a reduction of chlorophyll and carotene content in leaves compared to control. It also affected the leaf area of the maize seedlings. Maize leaf is an active site of photosynthetic activities, which is the primary location of food production. Plant

chlorophyll allows sunlight to change kinetic energy to potential energy and as such, maize leaf area could play an important role in the accumulation of organic materials. Some maize types could be more tolerant to heavy metal toxicity than others (Aliu *et al.,* 2013). Also, Godzik (1993) observed that maximum lead content was found in senescing leaves, while the minimum lead content was found in young leaves. This phenomenon explains why heavy metals could increase in concentration in storage parts of plants as the plant increases in age. From the literature, it could be deduced that in most cases the presence of heavy metals causes stress and inhibits or slows the growth processes of plants, including maize (Stiborova et al., 1987; Rascio et al., 1993).

2.10 Chicken: Physiology, Adaptation and Tolerance

Fowl applies mainly to edible species of birds commonly reffered to as chicken. Young birds of both sexes, such as, broilers and fryers are called chickens, while very young chickens of either sex are reffered to as chicks. Chickens are one of the most common and widespread domestic animals. Although their global population has decreased from more than 24 billion in 2003 to 19 billion in 2011, there are more chickens in the world than any other species of bird (Perrins, 2003).

In habit, chickens are diurnal, highly gregarious and polygamous. They exhibit high fecundity, which is an important characteristic because their eggs and meat are prized as food. They are adapted for living on ground, where they find their foods which are mostly green stuffs, seeds, insects and worms. Their feet are designed for scratching the earth, their crop is large and their gizzard is strongly muscular. Adults have comb on their head, which is more prominent in the male; but, absent in the young fowls (Perrins, 2003).

Exposure of the free-ranged chickens to soil pollutants is inevitable due to their mode of sourcing and acquiring food, which is through scavenging. Also, the characteristic of their feet, which is designed to scratch the soil for lower organisms particularly worms, insects among other might be exposed and contaminated with soil pollutants. Consequently, when chicken feeds on such contaminated food material, their systems acquire contaminants in quantities relative to the amount of contaminated organisms consumed (USPEA, 2012).

The chicks are precocial, that is, when hatched, are not naked; but, are covered with down feathers and so, they are immediately able to run around. Although they are able to feed themselves, newly hatched chicks can survive about a week without eating, subsisting on egg yolk that is included in the abdomen.

Broilers, *Gallus gallus domesticus* are chickens bred specifically for meat production (Kruchten, 2002). They are noted for having a very fast growth rates with a high feed conversion ratio. They often reach a slaughter weight of four to five pounds (dressed) in only five weeks, though some can reach it in about six to seven weeks. Those that are growing free-range and organic strains reach slaughter weight at 12 to 16 weeks of age (Damerow, 1995; USPEA, 2012). Both male and female can be reared for their meat, although at early age, they are not easily distinguishable. As a result of their fast growth, their behavior and physiology are those of immature birds rather than adults (Perrins, 2003).

Nociceptors, which respond to noxious stimulation, have been identified and physiologically characterized in many different parts of the body of the chicken, including the beak, mouth, nose, joint capsule and scaly skin. Stimulation of these nociceptors produces cardiovascular and behavioral changes consistent with those seen in mammals and is indicative of pain perception (Gentle, 2011). Chickens are omnivores and modern broilers are given access to a special diet of high protein feed, usually delivered via an automated feeding system. This is combined with artificial lighting conditions to stimulate growth; thus, the desired body weight is achieved in four to eight weeks, depending on the approximate body weight required by the processing plant (Redmond, 2008).

Chickens have very efficient cardiovascular systems that permit them to meet the metabolic demands. The avian circulatory system consists of a heart plus vessels that transport nutrients, oxygen and carbon dioxide, waste products, hormones and heat. They also have a 4-chambered heart with two (2) atria and two (2) ventricles, with complete separation of oxygenated and de-oxygenated blood. The right ventricle pumps blood to the lungs, while the left ventricle pumps blood to the rest of the body. Because the left ventricle must generate greater pressure to pump blood throughout the body, the walls of the left ventricle are much thicker and more muscular.

Physiological and behavioral experiments have identified the problem of acute pain, following environmental pollution (Gentle, 2011). Consequently, studies assessing avian toxicological importance relating to metal exposures, population status and reproductive success can be extrapolated to other wildlife and probably humans. Environmental stress may depress the immune function of birds by impeding production of antibodies and effective cell-mediated immunity (Zulkifli *et al*, 1994). The dietary characteristics which are the level of nutrients or type of ingredients can also modulate the susceptibility of birds to infectious challenges (Klasing, 1988).

Generally, birds are good sentinel species because they are observable, sensitive to toxicants, and live in different trophic positions. In addition, they have low level of activities which makes them much suitable for carrying out research studies (Custer and Osborn, 1977; Walsh, 1990; Prichard *et al*, 1997; Spalding *et al*, 1997). The use of blood examination as a way of assessing the health status of animals has been documented (Muhammad *et al*, 2000; Owoyele *et al*, 2003; Muhammad *et al*, 2004; Muhammad and Oloyede, 2009). This is because it plays a vital role in physiological, nutritional and pathological status of organisms (Muhammad *et al*, 2000; Muhammad and Oloyede, 2009). Haematological parameters are those parameters that are related to the blood and blood-forming organs (Stenesh, 1975; Muhammad and Oloyede, 2009). They range from giving the level of the blood to detecting ailment or disorders through them.

The erythrocytes is responsible for haemoglobin transport and also help in converting carbondioxide and water into carbonic acid and vice versa with the help of carbonic anhydrase enzyme. This helps in maintaining the acid base balance (osmotic regulation) in the avian body. RBCs are more in male birds than female because androgens increases RBC formation while oestrogen decreases it (Avian Physiology Lecture, 2012). In a bird's life, the RBCs are formed in the bone marrow as well as in the liver, spleen and thymus. RBCs has a lifespan of 28 to 35 days. The hormone controlling the formation of RBC (erythropoiesis) is secreted in the kidney and is called erythropoietin. It is glycoprotein hormone which increases at high altitudes. In birds, the bone marrow is responsible for the storage of RBC though an insignificant quatity is kept in the spleen like humans (Avian Physiology Lecture, 2012). The dead

and dying RBCs are removed by the phagocytes (monocytes) and Kupffer cells (stationary macrophages) in the liver (Avian Physiology Lecture, 2012).

The haemoglobin (Hb) is made by the red blood cells and it is between 8 to 12 g/dl in chicken blood. The haemoglobin helps in transporting oxygen and carbondioxide. Each haemoglobin usually carries four (4) oxygen molecules. The amount of Hb in RBC is the mean corpuscular haemoglobin (MCHb) and is an approximate value of about 50pg/cell while the relative volume of red blood cell's haemoglobin is the mean corpuscular haemoglobin concentration (MCHC) and is an approximate value of 25% (Avian Physiology Lecture, 2012).

The white blood cells (WBCs) are cells of the immune system, which defend the body against foreign materials and infectious diseases. It is derived from a multipotent cell, known as a haematopoetic stem cell and is found in the blood and lymphatic system. It is produced by the bone marrow, liver and lymphoid tissues (bursa of Fabricus, spleen, thymus and gut associated lymphoid tissues). WBCs can either be agranulocytes (monocytes: 5-15% WBCs and lymphocytes – 60 – 80% WBCs) or granulocytes (heterophils – 20 – 30% WBC, eosinophils – 1-3% WBC and basophils: 0.5 – 2% WBC). Thrombocytes is smaller than RBC, nucleated and is responsible for clotting and inflamation. It also phagocytize foreign particles.

It had been reported that biochemical changes as a result of toxins have effects on haematological parameters (John, 1998; Karnish, 2003; Levene and Gorgen, 2003; Muhammad and Oloyede, 2009). The effect of both raw and processed feed on the haematological parameters of animals have been reported in literature (Muhammad *et al*, 2000; Owoyele *et al*, 2003; Muhammad *et al*, 2004; Muhammad and Oloyede, 2009). The seed meal-based diet had equally been reported to affect the growth, haematological and some urinary parameters of rats (Muhammad *et al*, 2004; Muhammad and Oloyede, 2004; Muhammad and Oloyede, 2009). The effect of *A. niger*-fermented *T. catappa* seed meal-based diet on the growth of broilers had also been reported (Muhammad and Oloyede, 2009).

However, information on the uptake, bio-concentration and effects of accumulated heavy metals like Pb in corn grown for the purpose of feed formulation for chicks and adult birds in these consumers have not been documented, if at all existing.

Haematological assessment is a process of blood collection or phlebotomy for the purpose of monitoring the health of the animals and it is an important procedure that is frequently performed in the course of animal experimentation. This is achieved by obtaining serum samples. Three types of blood samples can be used for diagnostic testing: whole blood, plasma, and serum. Whole blood samples are usually used to examine, by microscopy, the condition of the erythrocytes (red blood cells), leukocytes (white blood cells), and thrombocytes (platelet-type cells); plasma samples are often used to obtain the chemical profile of the birds' blood, while serum samples are used to obtain antibody titer levels present to determine flock exposure to disease agents.

Chickens' blood samples can be collected from the large vein under the wing (brachial vein), the vein on the side of the outstretched neck (jugular vein), the vein on the inner leg, above the hock (medial metatarsal vein), anterior vena cava, wattles or comb and cardiac. Evaluation of the avian haemogram involves counting the various blood cells per microliter of blood as well as cytologic evaluation of the cells. Avian blood cells do not store well, hence; haematologic results obtained soon after collection are preferred over those performed several hours later (Campbell, 1988; Dein, 1986; Hawkey and Dennett, 1989).

Collection of a large volume of blood, or small volumes on a frequent basis, may reduce the number of circulating red blood cells, and reduce the oxygen-carrying capacity of the blood. Although there are limited stores of red blood cells in the spleen which can be used to rapidly replace losses, replacement in the longer term requires production by the bone marrow. This production in turn requires an adequate supply of nutrients to the bone marrow, including iron.

In general, birds are able to tolerate severe blood loss than mammals because of their greater capacity for extra-vascular fluid, though there is a marked variation among avian species in response to blood loss. This may be a reflection of differences in blood volume or extra-vascular fluid depots. Where the rate of replacement of red blood cells cannot balance the rate of depletion, anaemia may occur. The clinical signs of anaemia include pale mucous membranes (tongue, gums and ears); increased respiratory rate at rest and exercise intolerance (easily exhausted).

Examination of blood in a veterinary laboratory also enables detection of other signs, such as, reduced numbers of circulating red blood cells (red cell count), reduced proportion of red blood cells in blood (haematocrit %; packed cell volume PCV%), reduced haemoglobin in blood, presence of increased numbers of immature cells (reticulocytes) and presence of abnormal red blood cells. In addition, the determination of haematological parameters and plasma metabolite levels provides highly valuable information on the physiological state and form the cornerstone of medical diagnosis of diseases (Hauptmanova *et al*, 2006; Harr, 2002). Clinical haematology and blood chemistry are indications of various factors, such as, diseases, nutritional status, body condition, sex, age, diet, circadian rhythms, and captivity (Fudge, 2000). Therefore, knowledge of the blood constituents in birds is a relevant diagnostic tool, which can be useful physiological indicators (Perelman, 1999).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Description of Study Site

The study area is a semi-urban residential and agricultural area located on latitudes 7°24'28.1"N, longitudes 4°00'52.2"E and elevation 176m respectively (GISK, 2012). It contained a waste dumpsite located at Omilende village in Ikumapaiyi Area of Olodo community, northwest of Egbeda Local Government Area, Ibadan, Oyo-State. It is popularly referred to as Ori-Ile Waste Dumpsite. Figure 3.1 shows the map of Ibadan with the location of the study site. Figure 3.2 is the map of the study area (Ikumapaiyi-Olodo). It is a large and bare expanse of land of about 2 hectares, characterized with scanty vegetation (Figure 3.3). The most abundant group of vegetation on the waste dumpsite were the grasses, some of which included *Panicum clandestinum* (corn grass), *Muhlenbergia emersleyi* (bull grass) and *Echinopogon ovatus* (hedgehog grass). *Panicum clandestinum* were most abundant in areas surrounding the study site. The site was used as an unapproved waste dumpsite for battery wastes from the now closed down company called West African Battery Industry, who used to produce the battery known as 'Exide Battery'. It was also used as an informal lead recovery site by informal and local Used Lead Acid Battery operators.

The site slopes downward to a nearby stream named Omi-stream, which divides into two and flow perpendicular to the study site at the base of the slope (Latitude 07^{o}24'28.5"N, Longitude 004^{o}01'01.1"E). The stream empties into Omi-river. Also, leachate from the site was observed to have formed a pool near the stream at the base of the slope and often discharges into the stream when heavy rain falls.

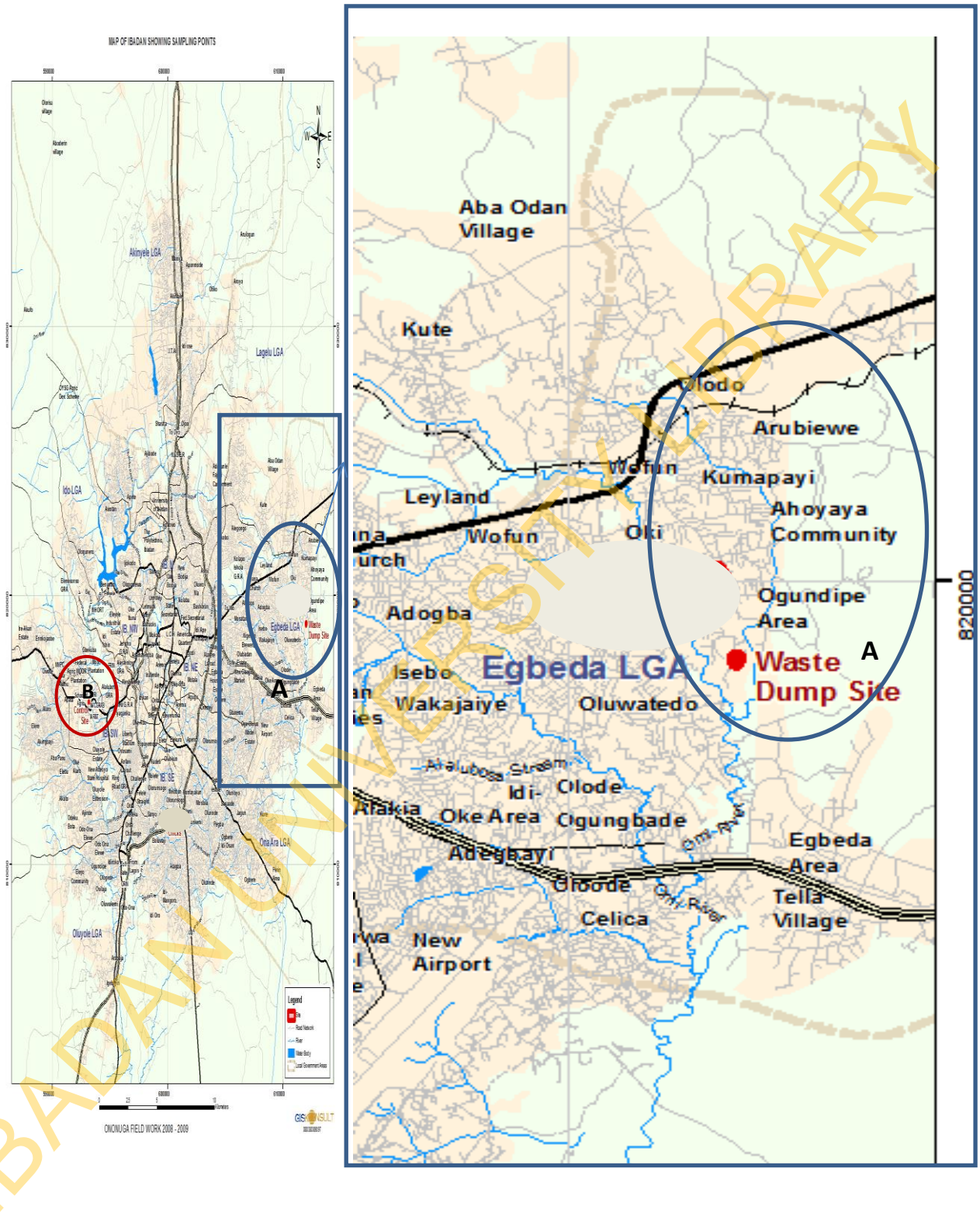


Figure 3.1: Map of Ibadan showing the Ori-Ile waste dumpsite (A) and control site (B).

Source: GIS Konsult, Bodija, Ibadan

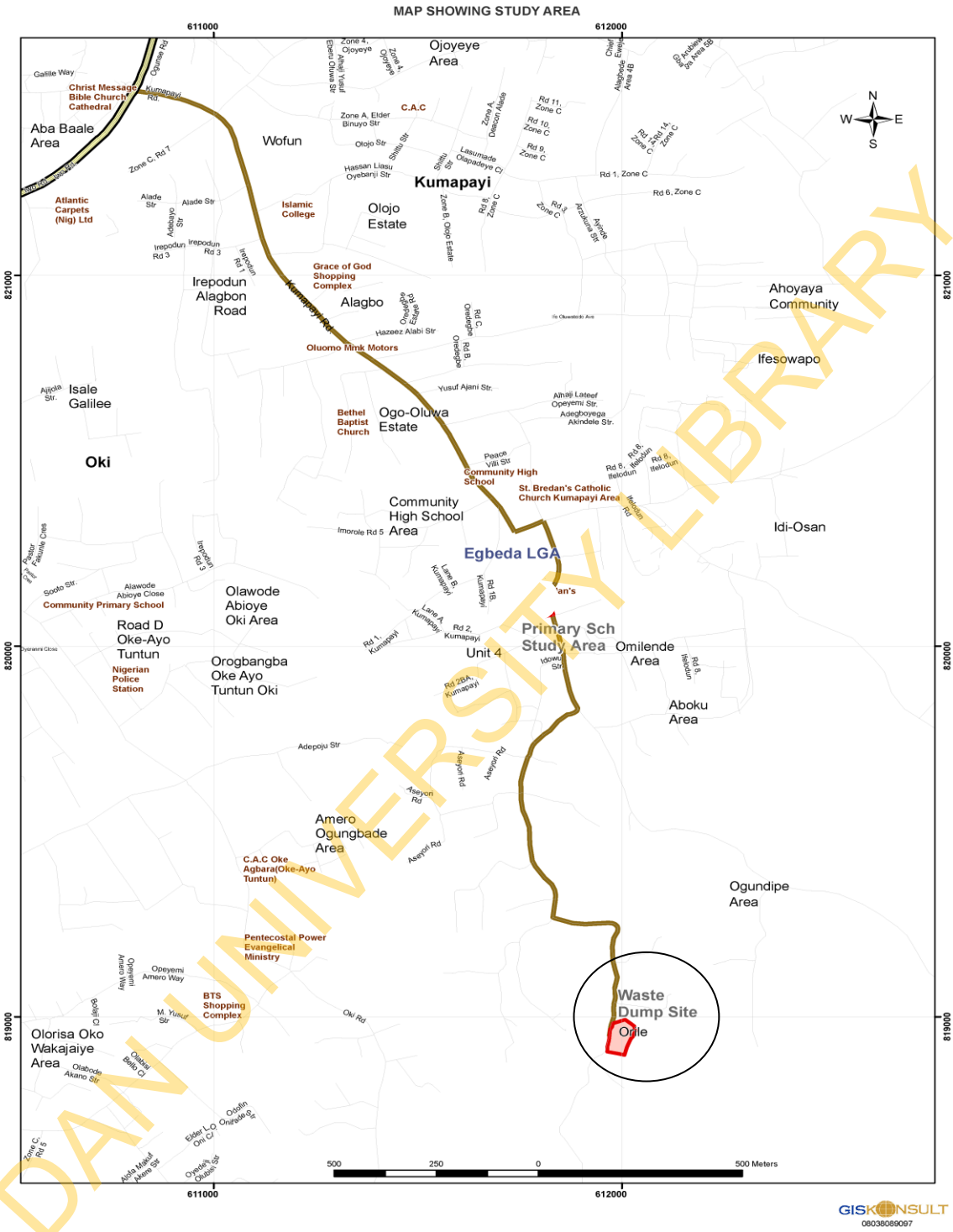


Figure 3.2: Map of Olodo showing the Ori-Ile waste dumpsite

Source: GIS Konsult, Bodija, Ibadan

Figure 3.3: Satellite Image of Omilende showing the Ori-Ile waste dumpsite

The area surrounding the waste dumpsite is inhabited by people who are mostly peasant farmers and traders. Domestic animals including *Gallus gallus domesticus* (both local and broiler chicken), *Capra aegagrus hircus* (Nigerian Dwarf Dairy Goat), etc. were being raised by residents living around the study area. Some of the residents also have gardens in their yard. Among the plants found in these gardens were *Zea mays*, *Carica papaya*, *Lycopersicon esculentum*, *Discorea sp* etc. In addition, residents depend on groundwater wells for their source of drinking water, though an occasional use of the stream water for other domestic purpose was done. Some of these well waters were chosen as groundwater sampling point and designated WWN, WWE, WWW and WWS while the Stream Water was sampled at upstream, midstream and downstream and these were designated as USW, MSW and DSW respectively. The control site was located at National Center for Genetic Resources and Biotechnology, Moor Plantation, Ibadan, latitude $7^{o}23'31.5''N$ and longitude $3^{o}50'46.5''E$.

3.2 Field Sampling and Analysis

The field study involved the bimonthly collection of the following samples:

- Topsoil (0-15 cm)
- Underground well water
- Surface water from Omi-stream in the study area
- Maize plant
- Free-range domestic chicks samples

These were obtained from the waste dumpsite and surroundings from March 2008 to August 2009.

3.2.1 Soil Sampling and Sample Processing

Soil samples were obtained bimonthly from March 2008 to August 2009 (no soil samples were collected in November, 2008) from the study site and control. The guidelines provided by USEPA (2000) were employed during sampling. The soil samples were taken at the top layer only (0-15cm deep) with the aid of the soil auger. Also, Geographical Positioning System (GPS) was employed in acquiring location information on specific points of sample collection. Table 1 shows the GPS data of the soil sampling points of the waste dumpsite and control.

Table 3.1: GPS data of soil sampling points of waste dumpsite and control

Gradient points	Sampling distance	No of samples per visit	Sampling points	GPS Coordinates		
				Elevation (m)	NORTH	EAST
North	0 m	One composite sample	AN0	174	07 24' 29.3"	004 00' 52.6"
			MN0	176	07 24' 28.1"	004 00' 52.2"
			BN00	172	07 24' 26.4"	004 00' 52.0"
	10 m	One composite sample	AN10	175	07 24' 29.4"	004 00' 52.3"
			MN10	172	07 24' 27.9"	004 00' 52.0"
			BN10	176	07 24' 26.2"	004 00' 51.6"
	20 m	One composite sample	AN20	176	07 24' 29.4"	004 00' 51.9"
			MN20	174	07 24' 27.9"	004 00' 51.6"
			BN20	178	07 24' 26.5"	004 00' 51.2"
	25 m	One composite sample	AN25	175	07 24' 29.4"	004 00' 51.8"
			MN25	170	07 24' 28.0"	004 00' 51.3"
			BN25	179	07 24' 26.6"	004 00' 51.1"
East	0 m	One composite sample	AE0	174	07 24' 29.3"	004 00' 52.6"
			ME0	172	07 24' 29.4"	004 00' 53.5"
			DE0	171	07 24' 29.2"	004 00' 54.4"
	10 m	One composite	AE10	174	07 24' 29.7"	004 00' 52.6"
			ME10	171	07 24' 29.6"	004 00' 53.6"

		sample	DE10	172	07 24' 29.5"	004 00' 54.5"
	20 m	One composite sample	AE20	171	07 24' 30.0"	004 00' 52.6"
			ME20	166	07 24' 29.9"	004 00' 53.8"
			DE20	170	07 24' 29.7"	004 00' 54.4"
	25 m	One composite sample	AE25	172	07 24' 30.2"	004 00' 52.8"
			ME25	170	07 24' 30.1"	004 00' 53.8"
			DE25	169	07 24' 29.9"	004 00' 54.5"
West	0 m	One composite sample	BW0	176	07 24' 26.5"	004 00' 51.9"
			MW00	173	07 24' 26.2"	004 00' 53.4"
			CW0	171	07 24' 26.1"	004 00' 54.4"
	10 m	One composite sample	BW10	181	07 24' 26.1"	004 00' 51.8"
			MW10	176	07 24' 25.9"	004 00' 53.4"
			CW10	171	07 24' 26.0"	004 00' 54.4"
	20 m	One composite sample	BW20	178	07 24' 25.8"	004 00' 51.6"
			MW20	178	07 24' 25.5"	004 00' 53.3"
			CW20	170	07 24' 25.6"	004 00' 54.5"
	25 m	One composite sample	BW25	179	07 24' 25.7"	004 00' 51.6"
			MW25	176	07 24' 25.4"	004 00' 53.3"
			CW25	170	07 24' 25.5"	004 00' 54.6"
South	0 m	One composite	CS0	167	07 24' 26.3"	004 00' 54.4"
			MS0	172	07 24' 27.2"	004 00' 54.4"

		sample	DS0	169	07 24' 28.9"	004 00' 54.6"
	10 m	One composite sample	CS10	169	07 24' 26.4"	004 00' 54.7"
			MS10	172	07 24' 27.1"	004 00' 54.7"
			DS10	171	07 24' 29.0"	004 00' 54.7"
	20 m	One composite sample	CS20	169	07 24' 26.4"	004 00' 55.0"
			MS20	171	07 24' 27.1"	004 00' 54.9"
			DS20	169	07 24' 28.9"	004 00' 55.0"
	25 m	One composite sample	CS25	168	07 24' 26.4"	004 00' 55.2"
			MS25	170	07 24' 27.1"	004 00' 55.0"
			DS25	167	07 24' 28.9"	004 00' 55.2"
Waste dumpsite sample	Rd	One composite sample	Rd1	173	07 24' 28.6"	004 00' 53.0"
			Rd2	174	07 24' 28.5"	004 00' 53.8"
			Rd3	175	07 24' 26.8"	004 00' 53.3"
			Rd4	175	07 24' 27.1"	004 00' 52.6"
Control	C	One sample			07 23' 31.5"	003 50' 46.5"

3.2.1.1 Soil Sampling, Digestion and Analysis

A total of one hundred and thirty six topsoil samples were collected every two months (March 2008 to August 2009) from the waste dumpsite and along each of North, South, East and West (N, S, E and W) directions at 5 m intervals from the edge of the waste dumpsite (Figure 3.4 and 3.5). The breakdown of sampling points is shown in Table 1 while the schematic diagram of soil sample collection is shown in Figure 3.4. The soil samples were collected with the aid of a soil auger and hand trowel into clean, labelled polythene sampling bags and sealed to prevent contamination during transportation to the laboratory. The sample bags were then taken to the laboratory for processing and analysis.

In the laboratory, each soil sample was air dried at room temperature for 2 weeks to remove its water content. The soil samples were then mixed uniformly while the coarse concretions, stones and pieces of macro-organic matter (roots, leaves and other vegetative material) were picked out (Kalra and Maynard, 1991). The dried soil samples were then homogenized by grounding in a porcelain mortar and sieved using a 2 mm mesh-sized sieve to further remove the remaining coarse particles and stones.

Using a weighing balance, 1.2 g each of the homogenized soil samples (from waste dumpsite and control) were measured in duplicates and kept in corked labeled plastic containers for digestion. The digestion of the samples was done according to the method adopted by Adie and Osibanjo (2009). This was done in a beaker covered with a watch glass and heated in a water bath. The 1.2 g homogenized soil samples were carefully put into cleansed and labeled 100ml beakers. To each of these beakers with a watch glass cover, 10 ml each of 2M Nitric acid (HNO_3) was measured with a pipette and added. The content of the vessel was then gently shaken to allow thorough mixing. The beaker was then left for an hour being placed on the water bath that had been set on the hot plate during the preparation and was boiling at $100^oC \pm 3^oC$. Heating was continued for 2 hours during which the beakers was intermittently shaken every 20 minutes until the volume of the beaker's content was reduced to about 2-5ml. At exactly 2 hours, the beakers were removed and allowed to cool. The digestate was filtered through Whatman No. 1 filter paper and the filtrates were collected in 100ml standard flasks using the funnels for anchorage.

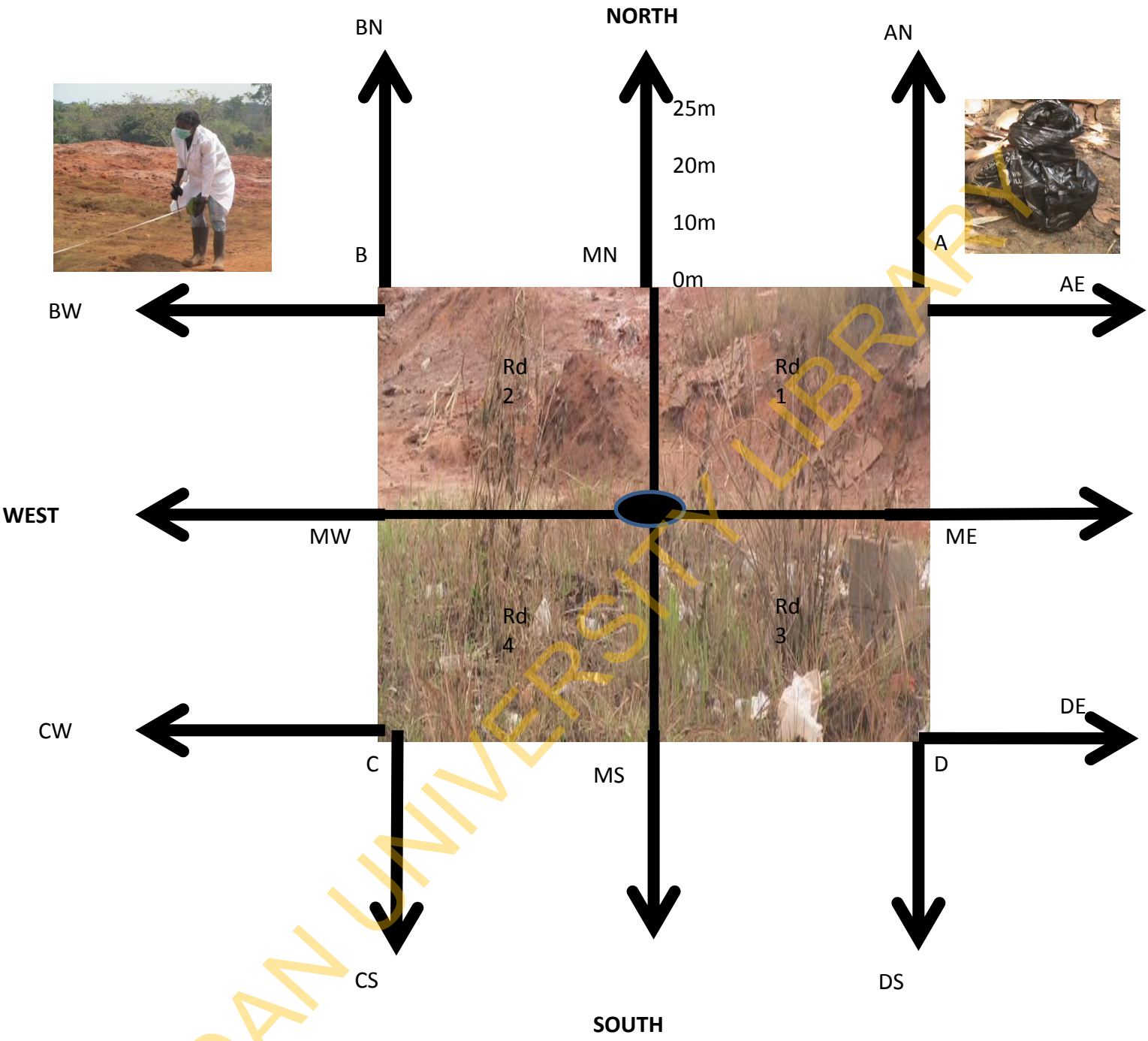


Figure 3.4: Schematic Diagram of Soil Sampling at Ori-Ile Waste Dumpsite

Figure 3.5: Satellite Image of Ori-Ile Waste dumpsite showing the soil sampling points

The filter papers were rinsed while still in the funnel with de-ionized water and the filtrate of the digested samples was made up to the final volume (100 ml) and kept for Atomic Absorption Spectrophotometric analyses. These were then analyzed for Pb, Cd and Fe with Perkin Elmer Analyst 200 Atomic Absorption Spectrophotometer (2003 Model). The procedure was repeated for all the samples and their replicates. Appropriate standards and blanks were prepared, analyzed and subtracted from the samples to correct for reagent impurities and other sources of errors.

3.2.1.2 Soil Particle Size and Porosity Determination

The particle size analysis was determined using the hydrometer method (IITA, 1979) and the porosity was determined using the Bouyoucous (1951) hydrometer method.

3.2.1.3 Soil pH Determination

The pH of the soil samples was determined with the aid of a calibrated Jenway glass electrode pH meter according to the procedure of ASTM, 1995.

3.2.1.4 Soil Cations Exchange Capacity (CEC), Percentage Base Saturation (PBS) and Soil Mineral Content (MC) Determination

Soil CEC was determined according to the method of Stewart (1989) while PBS and MC were determined according to the method of Tecator (1985).

3.2.1.5 Soil Organic Carbon and Organic Matter

Soil organic carbon and organic matter was determined using the Walkley and Black (1934) wet oxidation method.

3.2.2 Water Sampling and Sample Processing

3.2.2.1 Groundwater Sampling, Preservation and Analysis

With the aid of a clean plastic drawer and pre-washed labelled sample bottles, a total of thirty two groundwater samples were collected 25m away from the waste dumpsite along the north (N), South (S), East (E) and West (W) directions, once every two months for 18 months (Figure 3.6). The groundwater samples were designated WWN

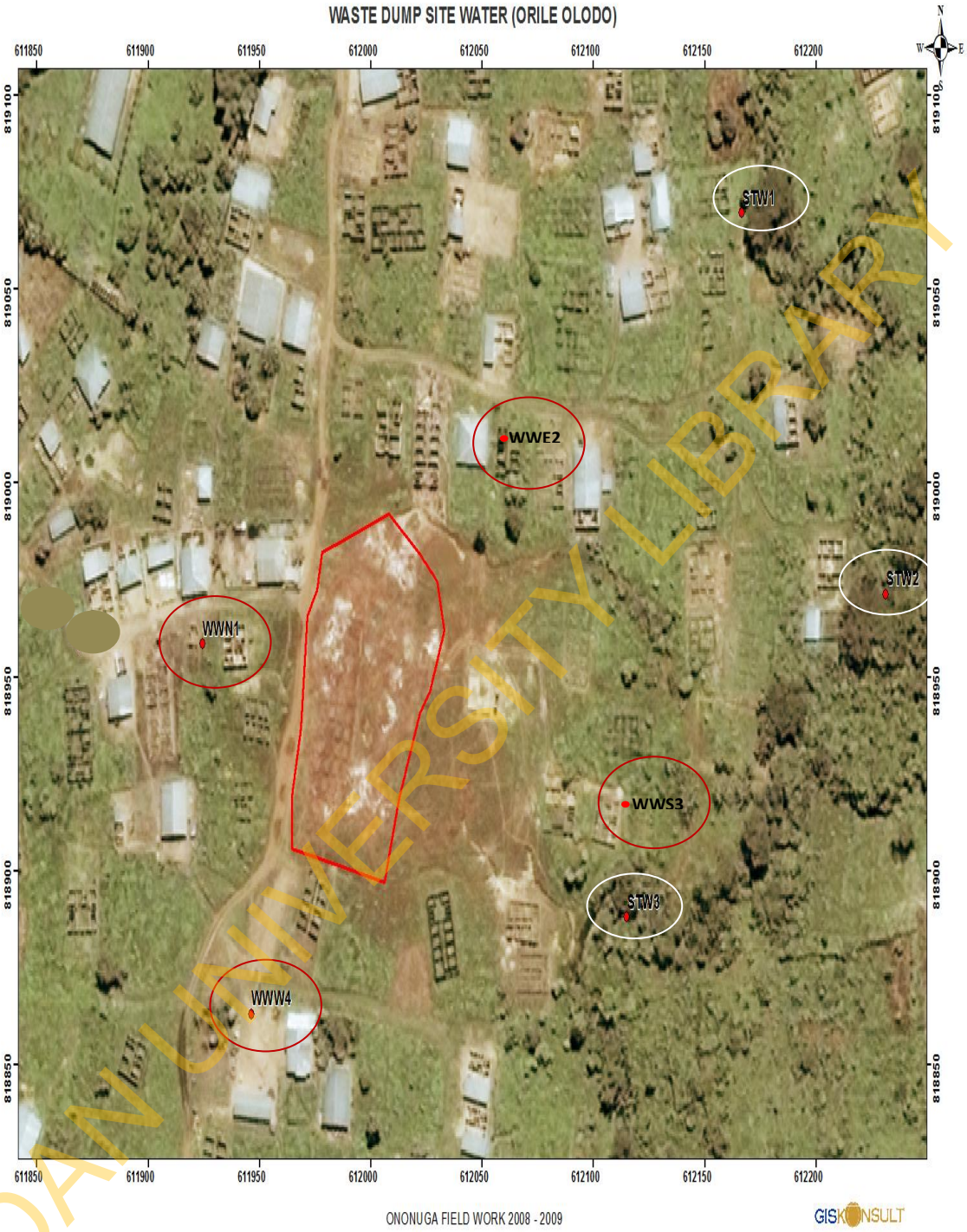


Figure 3.6: Satellite Image of Ori-Ile Waste dumpsite showing the water sampling points.

Key: WWN1, WWE2, WWS3 and WWW4 shows Groundwater well sampling points

STW1, STW2, and STW3 shows Stream water sampling points

(North – latitude 07°24'28.1"N, longitude 004°00'51.1"E), WWE (East – latitude 07°24'29.9"N, longitude 004°00'54.5"E), WWW (West – latitude 07°24'25.0"N, longitude 004°00'51.8"E) and WWS (South – latitude 07°24'27.1"N, longitude 004°00'55.0"E) respectively. Control groundwater samples were also taken from National Centre for Genetic Resources and Biotechnology, Moor plantation, Ibadan (latitude 7°23'31.5''N and longitude 3°50'46.5''E).

All samples were collected on the same day and kept in well labelled, two litres plastic bottles which had been previously washed with deionized water and rinsed with nitric acid (HNO_3). Immediately, few drops of HNO_3 were added in order to prevent loss of metals as well as bacterial and fungal growth.

All collected samples were taken to the laboratory and kept in the refrigerator at 4°C until when analyzed. These were then analyzed for Pb, Cd and Fe using Perkin Elmer Analyst 200 Atomic Absorption Spectrophotometer (2003 Model).

3.2.2.2 Surface Water Sampling, Preservation and Analysis

Surface water samples were randomly collected at three representative points (upstream, midstream and downstrream) along the stream. The samples were collected in pre-cleaned plastic bottles and this was labelled upstream water (USW) which was a point above where the waste dumpsite is located (latitude 07°24'31.7"N, longitude 004°00'59.0"E), midstream water (MSW) which was the point perpendicular to the waste dumpsite location (latitude 07°24'28.5"N, longitude 004°01'01.1"E) and downstream water (DSW) which was a point further down beyond the location of the waste dumpsite (Latitude 07°24'25.8"N, Longitude 004°00'57.3"E) respectively (Figure 3.6). Control stream water was taken from Moor plantation stream water (latitude 7°23'31.5''N and longitude 3°50'46.5''E) at National Centre for Genetic Resources and Biotechnology, Moor Plantation, Ibadan.

These samples were taken once every two months for 18months. Few drops of HNO_3 were added in order to prevent loss of metals, bacterial and fungal growth. Temperature and pH of water samples were also measured at the time of collection. The samples were taken to the laboratory and kept frozen in the refrigerator until when analyzed.

Pb, Cd and Fe were determined in the surface water samples using a Perkin Elmer Analyst 200 Atomic Absorption Spectrophotometer (2003 Model).

3.2.3 Maize Cultivation, Harvesting, Preservation and Analysis

3.2.3.1 Maize Cultivation, Harvesting and Preservation

The study was carried out on a nearby house garden, situated in direction with highest heavy metal concentration (latitude 07^{o}24'30.2"N, longitude 004^{o}00'52.8"E), within 25m distance away from the waste dumpsite, to determine the levels of uptake and accumulation of Pb, Cd, and Fe. This became necessary because of the previous study by Ononuga (2005), which showed that monocotyledons on the site had higher concentration of Pb than the dicotyledonous plants. Hence, this study involved the planting of one of the most cultivated and consumed monocotyledonous plants - maize in the waste dumpsite surrounding for heavy metal level analysis.

Four (4) maize seeds each were planted on fifty (50) ridges and out of these, only thirty (35) ridges had their maize germinated and grow till maturity. At maturity, the maize was harvested and the root, stem, leaf and maize-grains were collected in a clean polythene bag. These were then taken to the laboratory for further analysis. Also, some maize-grains were separated, air dried and kept for formulating feed for the experimental broiler chicks. Control maize samples were cultivated and harvested from a maize garden in National Centre for Genetic Resources and Biotechnology quarters, Moor plantation, Ibadan (latitude 7^{o}23’31.5’’N and longitude 3^{o}50’46.5’’E).

3.2.3.2 Maize Plant Analysis

To remove surface contamination, the harvested maize parts were gently brushed with a stiff-bristled brush followed by brief rinsing with de-ionized water to remove any debris prior to drying. The different maize-parts were oven- dried at 65^{o}C to constant weights, grounded in a porcelain mortar and sieved using a 2mm mesh-sized sieve (Jones *et al*, 1991).

The grounded samples (1.2g) were weighed into vitreosil crucibles and dry-ashed in a muffle furnace at 450-500^{o}C for 3hrs. The grayish-white ash was dissolved with 5ml of hot 6M nitric acid and evaporated on a hotplate. After evaporation, 1ml of 6M nitric acid was added followed by de-ionized water and then the sample solution was

filtered. The filtered extract was made up to 25ml with de-ionized water in a volumetric flask and then stored in well labeled, acid-washed plastic vials with screw caps prior to analysis (Jones *et al*, 1991).

Extracts of the different maize-part samples were then analyzed for Pb, Cd and Fe using Perkin Elmer Analyst 200 Atomic Absorption Spectrophotometer (2003 Model). A procedural blank sample analysis was also carried out as well.

3.3 Laboratory Experimental Procedures

3.3.1 Broiler Chicks Acquisition, Acclimatization and Preliminary Assessment

Prior to the acquisition of the broiler chicks, the animal house had been swept and washed with disinfectant. The floor of the pen had also been lined with clean and sterilized wood shavings. A 200 watt heat bulb was hung in the animal house to generate heat for the day-old chicks and the temperature of the room was checked using the thermometer to be 30^{o}C for the first day.

Thirty (30) broilers (one-day-old) were purchased from a reliable hatchery (Zartech Farms Ltd, Oluyole) in Ibadan. These chicks had been vaccinated before purchase. They were then transferred to the animal house where they were kept throughout the experimental period. Also, five additional (one-day old) chicks were purchased the same day for pre-assessment.

On arrival, the chicks were weighed, tagged and placed in the prepared animal house where they immediately redistribute themselves to the areas they prefer. All the birds were acclimatized together for a period of two weeks and they were exposed to the same sanitary, management and nutritional treatments throughout the period. They were fed *ad libitum* with a broiler starter diet and given clean drinking water for those first two weeks. Also, appropriate medications were administered to the birds during this period.

3.3.2 Broiler Chicks Exposure and Analysis

After acclimatization, the thirty (30) broiler chicks were subdivided into two equal groups (15 experimental chicks and 15 control chicks). The experimental broilers were then fed on Formulated Feed from Harvested Grains (FFHG) while the control broilers

were fed Formulated Feed from Control Grains (FFCG) for additional six weeks. Linear programming formulation method was used to formulate broiler feed with the percentage crude protein being 18.83-19.69%.

All the chicks were weighed at week 4, 6 and 8 of the experiments (Figure 3.7). Five chicks from each broiler group were sacrificed at four, six and eight-week old to determine Pb, Cd and Fe accumulation in their plasma, skin, liver and femur (Figure 3.8). Each of the chicks were randomly selected and fasted overnight before the blood collection and sacrificing.

Pb, Cd and Fe concentrations in each of the broiler's plasma, skin, liver and femur were determined using Perkin Elmer Analyst 200 Atomic Absorption Spectrophotometer (2003 Model). The broiler's liver and kidney were collected for histopathological analyses (Luna, 1968) while the plasma were also used for haematological analyses using standard procedures (Blaxhall and Daisley, 1973; Jain, 1986).

3.3.3 Domestic Chicks Acquisition and Analysis

In view of the fact that domestic animals like chicken scavenge freely around the site (Figure 3.9), five domestic free scarvenging chicks (eight weeks old) were purchased from Ori-Ile community from residents (Latitude 07^{o}24'30.2"N, Longitude 004^{o}00'52.8"E), within 25m distance away from the waste dumpsite. The control domestic chicks were obtained from Moor Plantation (MP), Ibadan. The chicks were weighed after purchase. All the chicks were then kept fasted overnight in the animal house and sacrificed the next day after their blood have been collected.

For each of sacrificed chicks, the blood, skin, liver and femur bone were collected, labelled and analyzed for Pb, Cd and Fe concentrations using Perkin Elmer Analyst 200 Atomic Absorption Spectrophotometer (2003 Model). Similarly, histopathological analysis of chicks' liver and kidney were done using standard procedure (Luna, 1968) and haematological analysis using their plasma was also done using standard procedure (Blaxhall and Daisley, 1973; Jain, 1986).

3.3.4 Atomic Absorption Spectrophotometer Analysis of Plasma, Skin, Liver and Femur of the Chicks

Plasma, skin, liver and femur samples of all the broilers (Experimental and control) and local chicks (from waste dumpsite and control) were collected in a well labelled transparent nylon (Figure 3.8), weighed and kept in the refrigerator (at -20 °C), prior to digestion. Also, the blood samples were collected from the jugular vein (neck vein) using a 5mm syringe into a well labelled EDTA bottle (Figure 3.10) and each of these were gently shaken to allow the blood-EDTA mixture to take place in order to prevent clotting of samples before they were centrifuged for plasma collection. The blood samples were centrifuged at 3000rpm for 10 minutes and the plasma was stored at -20^{o}C until used. From the centrifuged blood samples, the plasma was collected and labelled appropriately for the determination of Pb, Cd and Fe using Atomic Absorption Spectrophotometry.

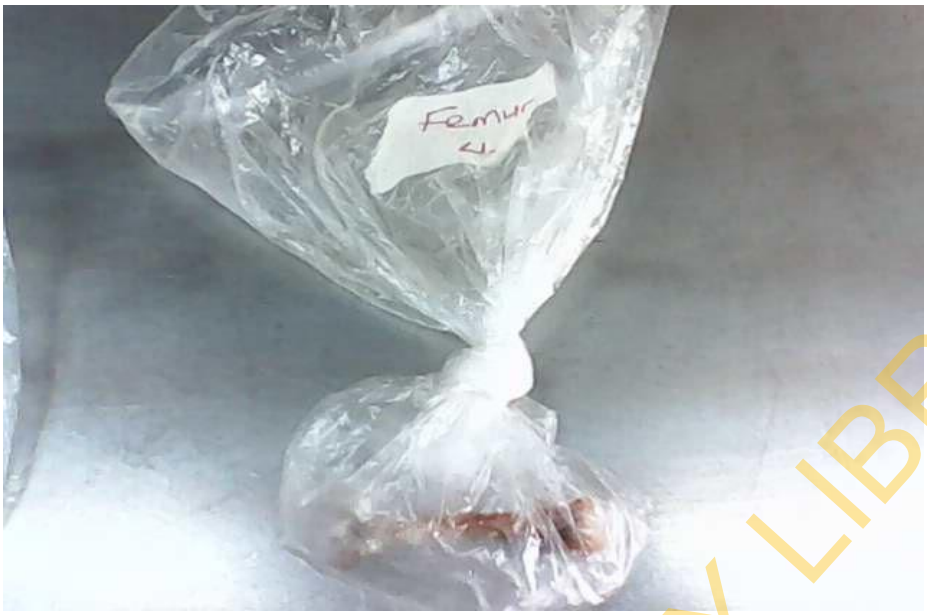
Analysis procedure for the liver, femur and skin samples was done according to the methodology described by Ferreira (2011). The liver, femur and skin samples were dried in an oven at 60 °C and homogenized. Approximately 300 mg of each homogenized dry sample were digested with 5 ml of 65% Nitric acid (HNO_3) and 0.3 ml of 70% Perchloric acid ($HClO_4$) at 80 °C for 24 hours. Afterwards, Perkin Elmer Analyst 200 Atomic Absorption Spectrophotometer (2003 Model) was used for the determination of Pb, Cd and Fe in the plasma, liver, skin and femur. Standard and blanks were analyzed along with each set of samples.

3.3.5 Procedure for Histopathological Analysis of the Samples

Immediatelly after the broiler chicks and domestic chicks were sacrificed, the liver and kidney samples were surgically excised and collected. These were each placed in a labelled container with 4% buffered formalin (Figure 3.11). The histopathological analysis was done according to the procedure of Luna (1968). Each of the samples were passed into a tissue processor for dehydration using a series of graded ethyl alcohol and they were also cleared in xylene. After this, they were embedded in melted parrafin wax and each of the wax block was then sectioned at about 5µm on a microtome to yield a thin slice of parrafin containing the tissue.

Plate 3.1: Measurement of Broiler chick's weight

a)



b)

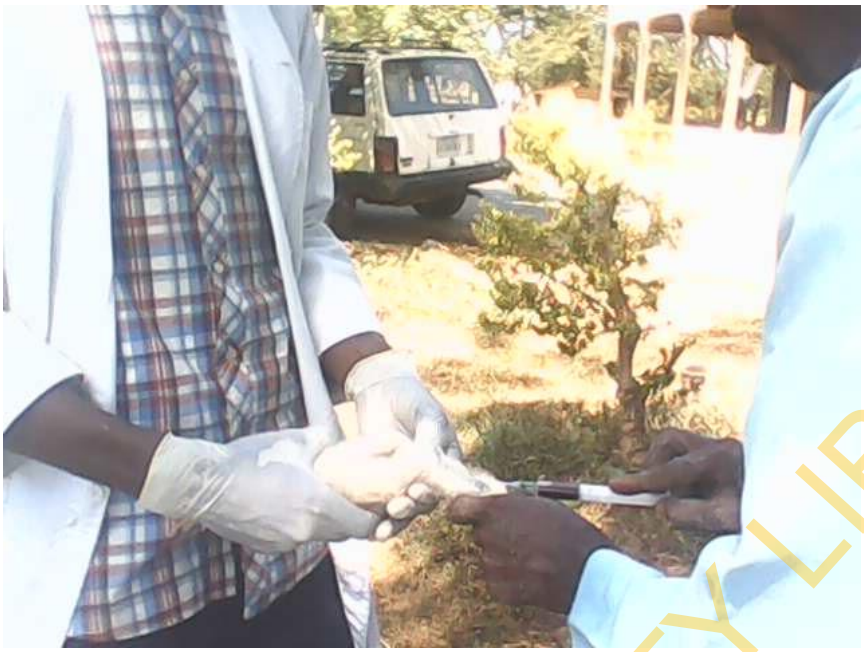
Plate 3.2: Polythene bags containing femur bone (a) and liver (b)

a)

b)

Plate 3.3: Scavenging free range local chicken around Ori-Ile Waste dumpsite

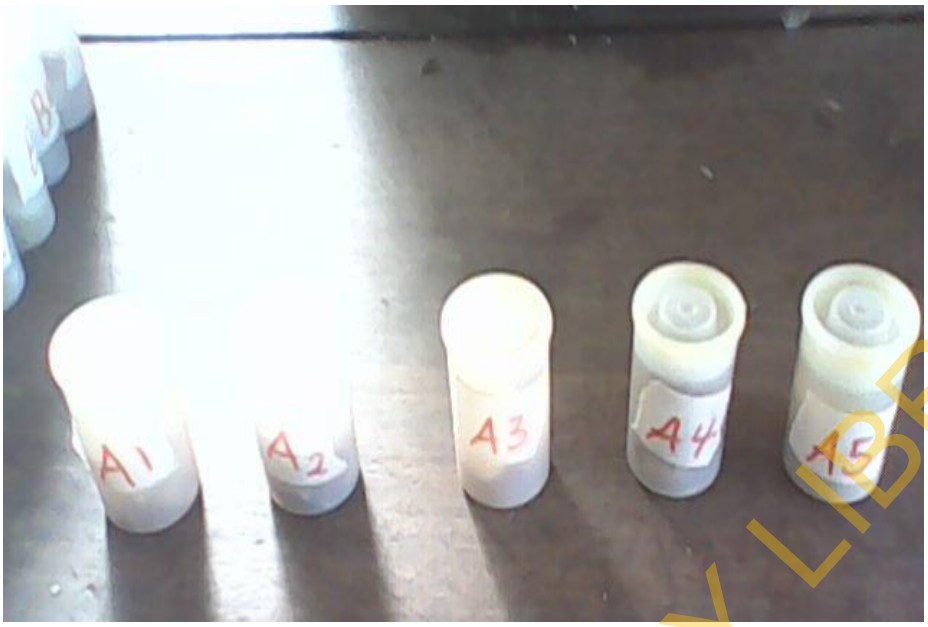
a)



b)

Plate 3.4: (a) Collection of chick's blood (b) collected blood samples in EDTA bottles

a)



b)

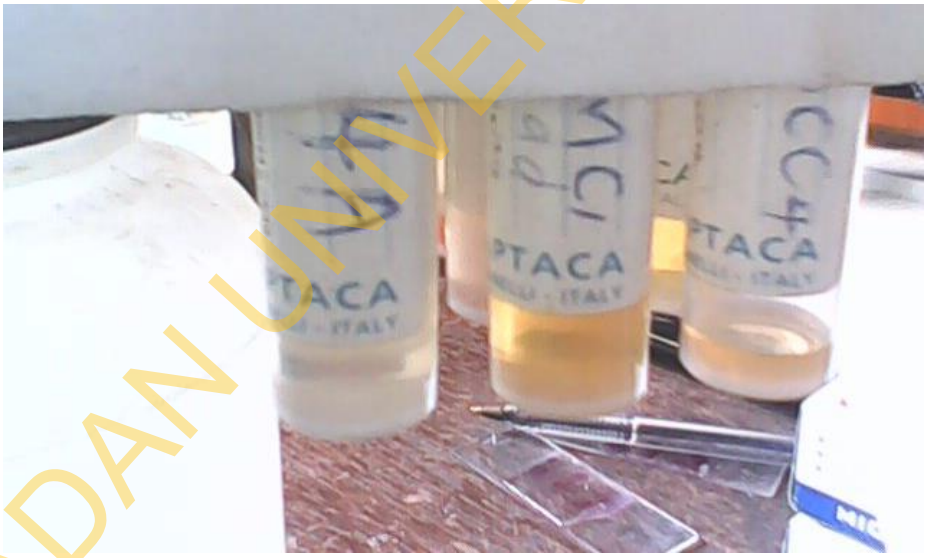


Plate 3.5: Samples for Histopathological (a) and Haematological (b) analyses

Then, two sections were mounted on glass slides, air dried and heated to cause the specimen to adhere to the glass slide. Residual parrafin was dissolved using toluene as a deparaffinizing solvents and the toluene was removed completely prior to staining. Each of the slides was stained with haematoxyline and eosin (H and E) stain and mounted in DEPEX (mountant). Haematoxyline colors nuclei of cells along with a few others, blue and Eosin colors eosinophilic other structures in various shades of red, pink and orange.

Excess haematoxyline was removed by rinsing with water while excess stain and water are removed by a series of sequential washes in a dehydrating reagent. The slides are then contacted with a chemical-clearing agent (toluene, xylene, or t-butanol) to remove residual dehydrating reagent remaining from the washing step. After the mountant have been applied to each slide, a cover slip was then applied after first removing the slide from the chemical-clearing agent. The clearing agent evaporates and the mountant hardens leaving a stained and mounted slide (Luna, 1968).

The slides were marked with the experimental identification numbers for all quantitative and qualitative evaluations while the histopathological assessment and photomicrography of the prepared slides was done using an Olympus light photomicroscope with attached Kodak digital camera. Each of the tissue sections was examined and their individual picture was taken in order to describe the histologic structures and histopathological conditions of the tissues. All the tissues were examined for histopathological conditions and the abnormalities seen were recorded.

3.3.6 Procedure for Haematological Analysis of the Blood Samples

With the aid of a 5ml syringe, blood was collected from each of the live birds at the neck vein (jugular blood collection) into a well labelled ethylenediaminetetraacetic acid (EDTA) bottles. All samples were collected within the same period (10am and 11am) to minimize variation in blood chemicals caused by the circadian rhythm. The blood samples were gently mixed with the EDTA to preserve them and also to prevent clotting. The tubes were kept on ice in cool containers to avoid denaturation of proteins and were taken to the laboratory within two hours of blood withdrawal. Haematological parameters were determined immediately at the Department of Veterinary Medicine Haematology Laboratory of the University of Ibadan.

Total erythrocyte and leukocyte count, packed cell volume and hemoglobin estimation were carried out in accordance to Blaxhall and Daisley (1973) while derived hematological values (MCV and MCHC) were calculated according to Jain (1986). In the laboratory, the micro-capillary tubes were centrifuged at 13,000 rpm for 5 min and the haematocrit values were determined directly in a micro-haematocrit reader. The red blood cell (RBC), white blood cell (WBC), and thrombocyte counts were determined with a haemo-cytometer using Natt-Herrick solution. The haemoglobin amounts were measured by Sahli's haemoglobinometer while the mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH), and mean corpuscular haemoglobin concentration (MCHC) were all calculated. Likewise, differential leukocyte counts were determined.

The procedure for determination of each of the haematological parameters was as follows:

a. **Haemoglobin Concentration**: Drabthius solution (pottassium ferricyanide, 200mg pottassium cyanide and 50mg pottassium dihydrogen phosphate) was added to 0.02ml of well mixed blood. Then, the volume was made up to 1litre with distilled water and adjusted to pH 7.0. The mixture was allowed to stand for three minutes and then read photometrically by comparing with a cyanomethaemoglobin standard with a yellow-green filter of 62.5nm.

b. **Packed Cell Volume (PCV)**: Plain capillary tubes were three-quarter filled by suction of blood sample with one end sealed with flame. The tubes were centrifuged for five minutes in a micro-haematocri centrifuge at 12,000G. The PCV was read with haematocrit reader (Kelly, 1979 model).

c. **Red Blood Cell Count**: The RBC count was done by diluting blood to 1:200 with Dacies fluid (99ml of 3% aqueous solution of sodium citrate and 1ml of 40% formalin) to keep and preserve the shape of the cells. The counting was then carried out with the aid of Newbauer haematocytometer (Kelly, 1979 model).

d. **White Blood Cell Count**: The WBCs were counted by diluting blood to 1:20 using 2 to 3% aqueous solution of acetic acid to which gentian violet (GV) was

added. The counting was done with Newbauer haematocytometer (Kelly, 1979 model).

e. **Mean Corpusular Volume (MCV)**: This is the mean volume of a single red cell. It was estimated as follows:

$$MCV = \frac{PCV\ \% \times 10}{RBC\ (10^6)\ fl(ferritolitres)}$$

f. **Mean Corpusular Haemoglobin (MCH)**: $MCH = \frac{RBC \times 100}{Hb\ g/\mu l\ (microlitres)}$

g. **Mean Corpusular Haemoglobin Concentration (MCHC)**:

$$MCHC = \frac{RBC \times 100}{PCV\ g/dl\ (decilitres)}$$

3.4 Quality Control/Assurance

Soil samples were collected with plastic-made implements to avoid metal contamination. Samples were kept in polythene bags that were free from heavy metals and organics as well as were well covered while transporting from field to the laboratory to avoid contamination from the environment. Reagent blanks were used in all analyses to check reagent impurities and other environmental contaminations during analyses. Analytical grade reagents were used for all analyses. All reagents were standardized against primary standards to determine their actual concentrations. All glassware used were soaked in appropriate dilute acids overnight and washed with teepol and rinsed with deionised water before use. All instruments used were calibrated and in good working condition before use. Tools and work surfaces were carefully cleaned for each sample during grinding to avoid cross contamination. Duplicate samples were analyzed to check precision of the analytical method and instrument. To validate the analytical procedures used, the spike recovery test was conducted on some soil samples for Pb and Cd.

3.5 Calculated Factors

Contamination, Bio-concentration and Bio-accumulation Factors (CF, B_cF and B_aF) were determined for soil, maize and chicks respectively using standard methods of Agunbiade and Fawale, 2009.

1. Contamination Factor (CF) is often used to access soil contamination through the comparison of the concentrations in the surface layer to the background values. It is calculated using the equation:

   $CF = C_{(0-1)} / C_n$ (Where CF = contamination factor; $C_{(0-1)}$ = mean of concentrations of individual metal from all test sites; C_n = baseline or background concentration of individual = concentration of metals at control site).

   $CF < 1$ = low contamination factor

   $1 < CF < 3$ = moderate contamination factor

   $3 < CF < 6$ = considerable contamination factor

   $CF > 6$ = very high contamination factor

2. Transfer Factor (TF): This is the concentration of each of the metal in the maize relative to the level of the metal in the corresponding soil.

   $TF = C_p / C_s$ (Where C_p = concentration of the metal in the plant (maize) while C_s = concentration of the metal in the corresponding soil).

   $TF > 1$ = High level of accumulation of metal in the plant

3. Bio-accumulation Factors (B_aF) of the metal into the chicks is the concentration of the metal in the tissue of the chicks relative to the concentration of the metal in the corresponding diet (maize).

   $B_aF = T_c / D_c$ (Where T_c =Tissue concentration while D_c = Diet concentration).

   $B_aF > 1$ = High level of accumulation of metal in the tissue of the chick.

4. Pollution Load Index (PLI): is used to evaluate the severity of pollution of the soils and plants according to the definition of Tomlinson *et al.* (1980). It is calculated using the equation:

   $PLI = [\pi^{n} i (c_{fi})]^{1/n}$

   Where, Cfi is the concentration factor of each metal obtained by the ratio of concentration of each metal in soil or plant to that of the metal in baseline soil or plant; π is the geometrical mean operator; n is the number of metals investigated and *i* is each metal. When PLI value is below or close to one, it indicates heavy metal loads at the baseline, while values above one indicate heavy metal accumulation or pollution in plant or soil from the test site.

3.6 Statistical Analysis

Statistical Analysis Software (SAS) package was used for the statistical analysis. The results of all the soil samples were grouped and analyzed using factorial tool to compress the data and identify patterns of relationship within them. Also, Duncan's Multiple Range Test of similarity was used to show the similarities within them.

The results of all the groundwater and surface water samples were analyzed for statistical differences and similarities using Analysis of Variance (ANOVA) and Duncan's Multiple Range Test of similarity respectively.

The results of the maize, broiler chicks and local chicks were analyzed for level of significance using the Student's T-test. This was done in order to determine the existing relationship between the different independent and dependent variables as revealed by the data obtained.

Data for each parameter were grouped and results were expressed as mean ± SD. The level of statistical significance was estimated at P= 0.05. Correlations between heavy metal residues (in terms of the inter-relationships) in the different samples were made by determining the correlation coefficient.

CHAPTER FOUR
RESULTS

The results of the bimonthly analysis carried out on different samples from Ori-Ile waste dumpsite, Ikumapaiyi Olodo area namely topsoil, underground well water, stream water, maize plant, broiler chicks and free-range local chicks are presented in this chapter.

4.1 Lead, Cadmium and Iron Concentrations in Topsoil Samples

The concentrations of lead, cadmium and iron measured in the different topsoil samples (0-15cm) from the suface of the Ori-Ile waste dumpsite, its fringes (0-25m along the gradient points) compared to values obtained from control site are presented in the following sections. These were compared with the NESREA standard limits, where values are available (Appendix 1).

4.1.1 Lead

4.1.1.1 Bimonthly Variation in Lead Concentration of Random Waste Dumpsite Sample, Each Gradient Point Distance and Control

Lead concentrations in the topsoil samples collected from the waste dumpsite (random sample) ranged from 2670.0 mg/kg in May 2009 to 7210.0 mg/kg in September 2008 with a mean and standard deviation of 4273.8±1436.7 mg/kg (Figure 4.1 and 4.2). Lead concentrations in the topsoil of distance 0 m along the North gradient point direction from the edge of the waste dumpsite ranged from 2986.7 mg/kg in May 2009 to 7136.7 mg/kg in September 2008 with a mean and standard deviation of 4693.8±1227.7 mg/kg. Lead concentrations in the topsoil of distance 10 m along the North gradient point direction from the edge of the waste dumpsite ranged from 2540.0

mg/kg in May 2009 to 6633.3 mg/kg in September 2008 with a mean and standard deviation of 4436.7±1277.4 mg/kg. Lead concentrations in the topsoil of distance 20 m along the North gradient point direction from the edge of the waste dumpsite ranged from 2646.7 mg/kg in May 2009 to 4833.3 mg/kg in September 2008 with a mean and standard deviation of 3678.3±673.0 mg/kg. Lead concentrations in the topsoil of distance 25 m along the North gradient point direction from the edge of the waste dumpsite ranged from 2473.3 mg/kg in May 2009 to 4300.0 mg/kg in September 2008 with a mean and standard deviation of 3245.8±555.2 mg/kg (Figure 4.1).

Lead concentrations in the topsoil of distance 0 m along the South gradient point direction from the edge of the waste dumpsite ranged from 3016.7 mg/kg in March 2008 to 6096.7 mg/kg in September 2008 with a mean and standard deviation of 4353.3±1052.0 mg/kg. Lead concentrations in the topsoil of distance 10 m along the South gradient point direction from the edge of the waste dumpsite ranged from 3440.0 mg/kg in May 2008 to 5653.3 mg/kg in September 2008 with a mean and standard deviation of 4138.3±732.2 mg/kg. Lead concentrations in the topsoil of distance 20 m along the South gradient point direction from the edge of the waste dumpsite ranged from 2580.0 mg/kg in May 2009 to 5033.3 mg/kg in September 2008 with a mean and standard deviation of 3612.5±743.9 mg/kg. Lead concentrations in the topsoil of distance 25 m along the South gradient point direction from the edge of the waste dumpsite ranged from 2203.3 mg/kg in May 2009 to 3703.3 mg/kg in September 2008 with a mean and standard deviation of 3137.5±355.2 mg/kg (Figure 4.1).

Lead concentrations in the topsoil of distance 0 m along the East gradient point direction from the edge of the waste dumpsite ranged from 3056.7 mg/kg in May 2008 to 6080.0 mg/kg in September 2008 with a mean and standard deviation of 4351.3±1068.2 mg/kg. Lead concentrations in the topsoil of distance 10 m along the East gradient point direction from the edge of the waste dumpsite ranged from 2980.0 mg/kg in May 2008 to 5413.3 mg/kg in September 2008 with a mean and standard deviation of 4186.7±762.0 mg/kg. Lead concentrations in the topsoil of distance 20 m along the East gradient point direction from the edge of the waste dumpsite ranged from 2926.7 mg/kg in May 2009 to 4730.0 mg/kg in September 2008 with a mean and standard deviation of 3775.8±527.8 mg/kg. Lead concentrations in the topsoil of distance 25 m along the East gradient point direction from the edge of the waste

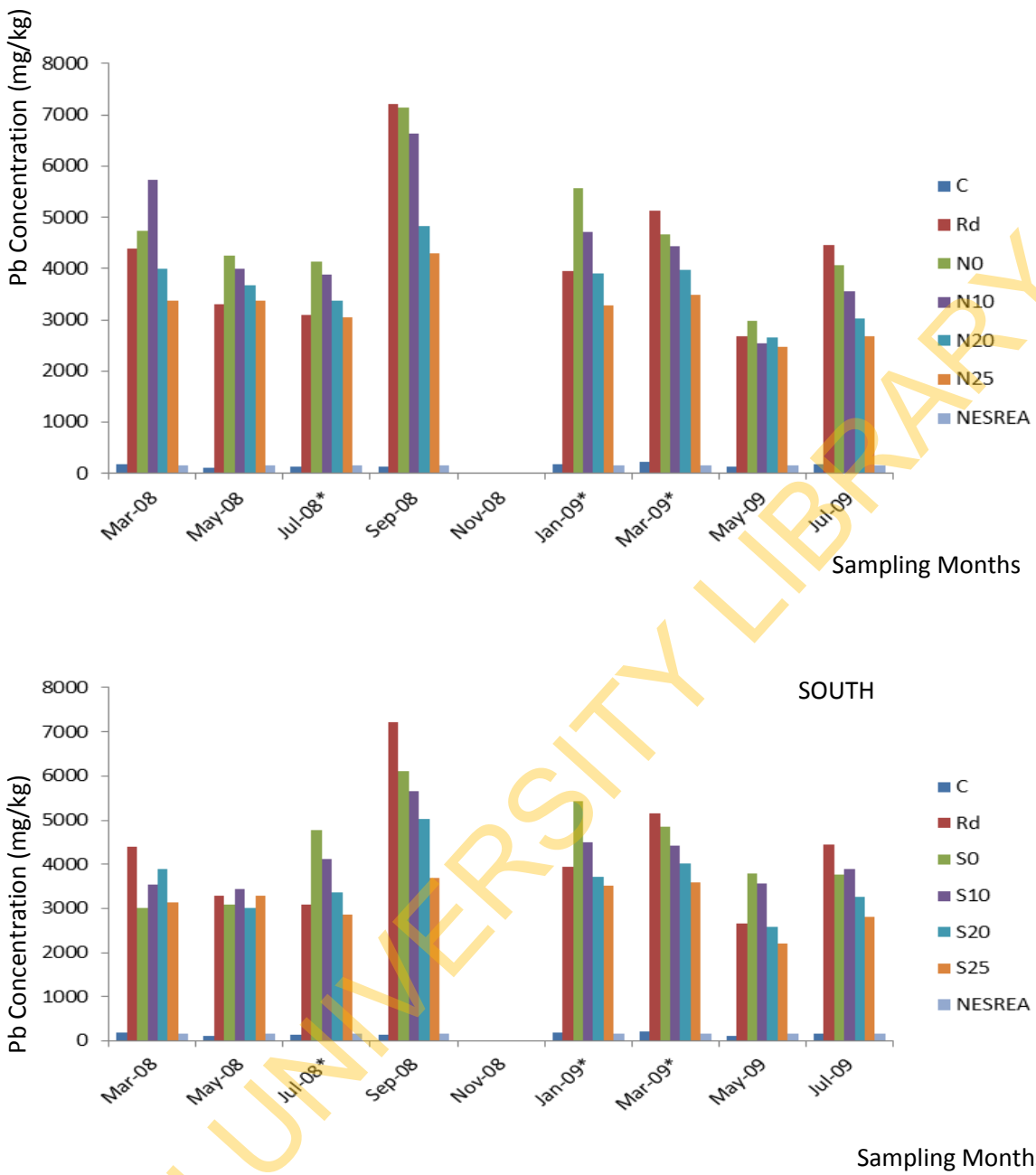


Figure 4.1 Bimonthly Concentration of Lead in Soils of Waste Dumpsite (Rd), North and South Samples

Key: * = significant.

Each bar	sampling months	Rd	waste dumpsite	N	North
successive colors	collection points' lead content	C	Control	S	South

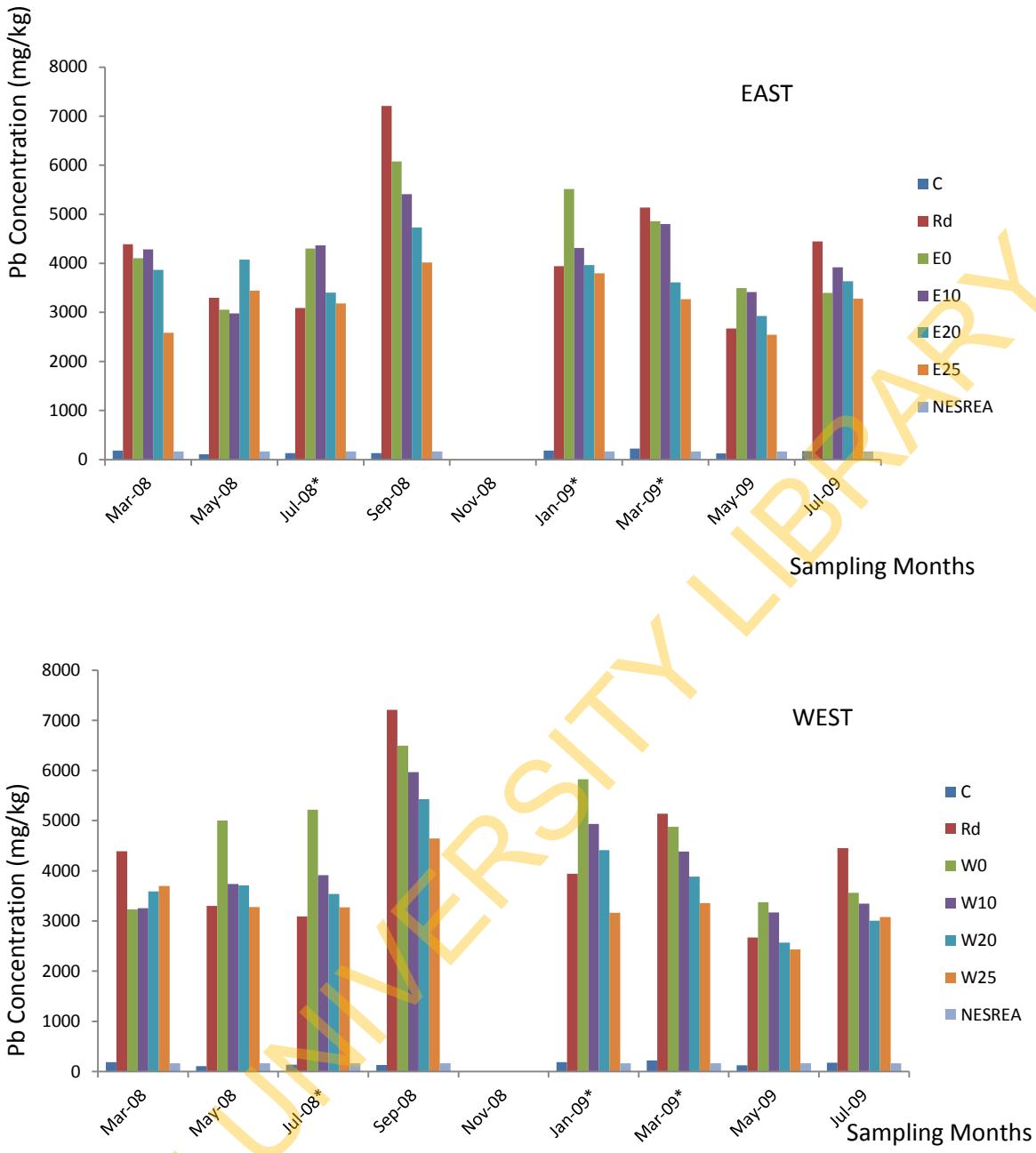


Figure 4.2 Bimonthly Concentration of Lead in Soils of Waste Dumpsite (Rd), East and West Samples

Key: * = significant.

Each bar	sampling months	Rd	waste dumpsite	E	East
successive colors	collection points' lead content	C	Control	W	West

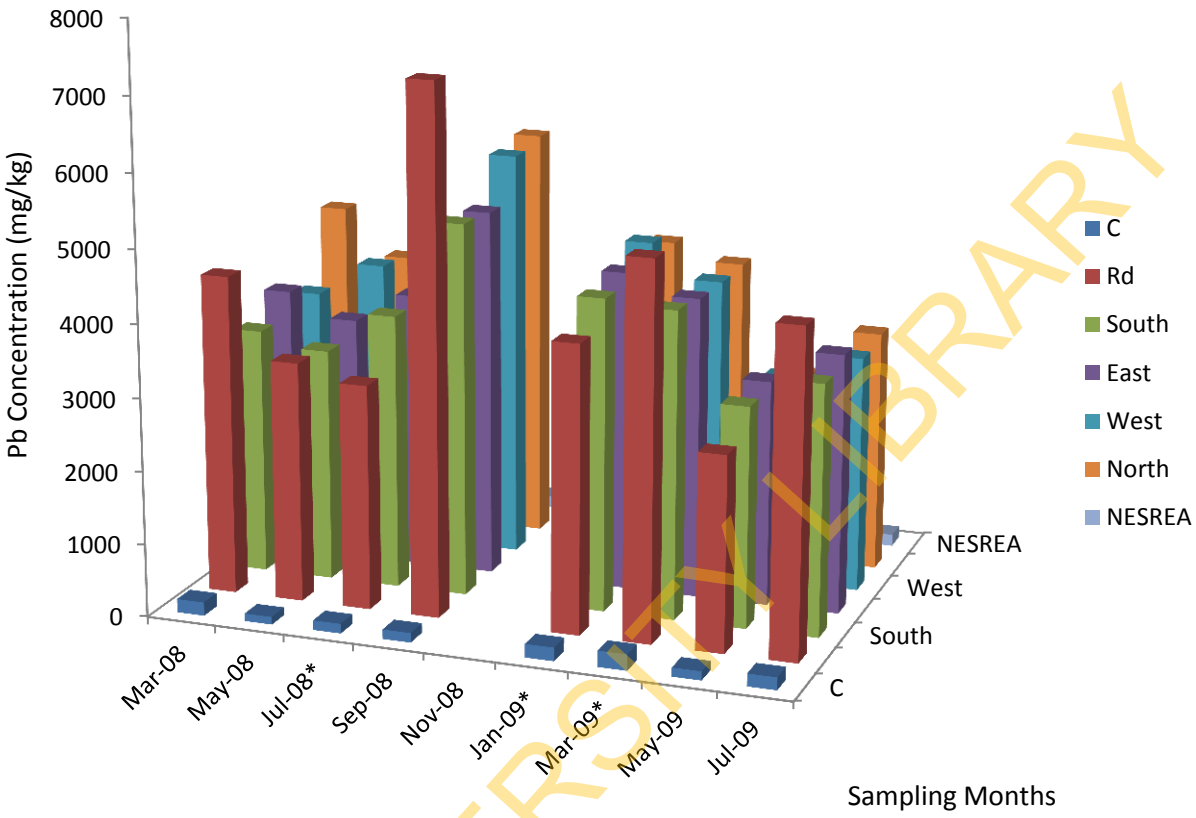


Figure 4.3 Mean Bimonthly Lead Concentrations in Soils of Ori-Ile Waste Dumpsite and Surrounding Gradient Points

Key:

Each bar	Mean lead concentration across distance in each gradient points
C	Control
Rd	Random waste dumpsite samples
Months with *	significant at p= 0.05

dumpsite ranged from 2543.3 mg/kg in May 2009 to 4020.0 mg/kg in September 2008 with a mean and standard deviation of 3265.8±517.8 mg/kg (Figure 4.2).

Lead concentrations in the topsoil of distance 0 m along the West gradient point direction from the edge of the waste dumpsite ranged from 3233.3 mg/kg in March 2008 to 6493.3 mg/kg in September 2008 with a mean and standard deviation of 4698.3±1199.3 mg/kg. Lead concentrations in the topsoil of distance 10 m along the West gradient point direction from the edge of the waste dumpsite ranged from 3170.0 mg/kg in May 2009 to 5966.7 mg/kg in September 2008 with a mean and standard deviation of 4088.8±960.1 mg/kg. Lead concentrations in the topsoil of distance 20 m along the West gradient point direction from the edge of the waste dumpsite ranged from 2566.7 mg/kg in May 2009 to 5430.0 mg/kg in September 2008 with a mean and standard deviation of 3766.7±870.4 mg/kg. Lead concentrations in the topsoil of distance 25 m along the West gradient point direction from the edge of the waste dumpsite ranged from 2433.3 mg/kg in May 2009 to 4646.7 mg/kg in September 2008 with a mean and standard deviation of 3366.3±627.9 mg/kg (Figure 4.2).

Lead concentrations in the topsoil of the control site ranged from 105.0 mg/kg in May 2008 to 221.5 mg/kg in March 2009 with a mean and standard deviation of 157.0±39.8 mg/kg (Figure 4.1 and 4.2).

The ANOVA results showed that the differences in mean values for the sampling months within the study site, were not significant at p=0.05 except July 2008, January 2009 and March 2009 (Figure 4.3).

4.1.2.2 Variation with Distance in Lead Concentration of Topsoil along the Gradient Points and the Random Waste Dumpsite

The results showed decline in mean lead concentration along the North (N), South (S), East (E) and West (W) gradient points as the distance increases from 0 m to 25 m from the edge of the waste dumpsite. Overall, there was a similar pattern of lead distribution along the distances 0 m to 25 m in each of the gradient points and it follows the order 0 m > 10 m > 20 m > 25 m (Figure 4.1 and 4.2).

The highest mean lead concentration in all the gradient points was at 0 m, which is at the edge of the waste dumpsite. Hence, only mean lead concentration of distances

N0m, S0m, W0m, E0m and N10m were higher in most cases as that of the random sample of the waste dumpsite (Rd) (Figure 4.1 and 4.2).

4.1.2 Cadmium

4.1.2.1 Bimonthly Variation in Cadmium Concentrations of Waste Dumpsite Random Sample (Rd), Each Gradient Point Distance and Control

Cadmium concentrations in the topsoil samples collected from the waste dumpsite (random sample) ranged from 122.0 mg/kg in May 2009 to 527.0 mg/kg in September 2008 with a mean and standard deviation of 258.4±123.1 mg/kg (Figure 4.4 and 4.5). Cadmium concentrations in the topsoil of distance 0 m along the North gradient point direction from the edge of the waste dumpsite ranged from 140.0 mg/kg in May 2009 to 518.3 mg/kg in September 2008 with a mean and standard deviation of 274.3±116.4 mg/kg. Cadmium concentrations in the topsoil of distance 10 m along the North gradient point direction from the edge of the waste dumpsite ranged from 134.7 mg/kg in May 2009 to 455.7 mg/kg in September 2008 with a mean and standard deviation of 247.5±108.9 mg/kg. Cadmium concentrations in the topsoil of distance 20 m along the North gradient point direction from the edge of the waste dumpsite ranged from 122.7 mg/kg in May 2009 to 263.3 mg/kg in September 2008 with a mean and standard deviation of 183.5±46.5 mg/kg. Cadmium concentrations in the topsoil of distance 25 m along the North gradient point direction from the edge of the waste dumpsite ranged from 119.7 mg/kg in May 2009 to 223.0 mg/kg in September 2008 with a mean and standard deviation of 150.0±32.2 mg/kg (Figure 4.4).

Cadmium concentrations in the topsoil of distance 0 m along the South gradient point direction from the edge of the waste dumpsite ranged from 157.0 mg/kg in May 2008 to 396.3 mg/kg in September 2008 with a mean and standard deviation of 255.2±92.0 mg/kg. Cadmium concentrations in the topsoil of distance 10 m along the South gradient point direction from the edge of the waste dumpsite ranged from 151.7 mg/kg in May 2008 to 355.7 mg/kg in September 2008 with a mean and standard deviation of 215.9±62.9 mg/kg. Cadmium concentrations in the topsoil of distance 20 m along the South gradient point direction from the edge of the waste dumpsite ranged from 122.0 mg/kg in May 2009 to 306.7 mg/kg in September 2008 with a mean and standard deviation of 186.9±60.0 mg/kg. Cadmium concentrations in the topsoil of distance 25

m along the South gradient point direction from the edge of the waste dumpsite ranged from 113.7 mg/kg in May 2009 to 180.7 mg/kg in March 2008 with a mean and standard deviation of 157.3±24.5 mg/kg (Figure 4.4).

Cadmium concentrations in the topsoil of distance 0 m along the East gradient point direction from the edge of the waste dumpsite ranged from 152.7 mg/kg in July 2008 to 394.3 mg/kg in September 2008 with a mean and standard deviation of 248.2±93.0 mg/kg. Cadmium concentrations in the topsoil of distance 10 m along the East gradient point direction from the edge of the waste dumpsite ranged from 145.3 mg/kg in May 2008 to 333.3 mg/kg in September 2008 with a mean and standard deviation of 224.3±60.8 mg/kg. Cadmium concentrations in the topsoil of distance 20 m along the East gradient point direction from the edge of the waste dumpsite ranged from 151.7 mg/kg in May 2009 to 273.0 mg/kg in September 2008 with a mean and standard deviation of 193.6±40.4 mg/kg. Cadmium concentrations in the topsoil of distance 25 m along the East gradient point direction from the edge of the waste dumpsite ranged from 141.7 mg/kg in March 2009 to 204.0 mg/kg in January 2009 with a mean and standard deviation of 164.0±23.2 mg/kg (Figure 4.5).

Cadmium concentrations in the topsoil of distance 0 m along the West gradient point direction from the edge of the waste dumpsite ranged from 146.7 mg/kg in March 2008 to 464.3 mg/kg in September 2008 with a mean and standard deviation of 278.4±111.9 mg/kg. Cadmium concentrations in the topsoil of distance 10 m along the West gradient point direction from the edge of the waste dumpsite ranged from 154.3 mg/kg in July 2009 to 382.7 mg/kg in September 2008 with a mean and standard deviation of 223.1±79.7 mg/kg. Cadmium concentrations in the topsoil of distance 20 m along the West gradient point direction from the edge of the waste dumpsite ranged from 121.0 mg/kg in May 2009 to 325.7 mg/kg in September 2008 with a mean and standard deviation of 192.3±69.6 mg/kg. Cadmium concentrations in the topsoil of distance 25 m along the West gradient point direction from the edge of the waste

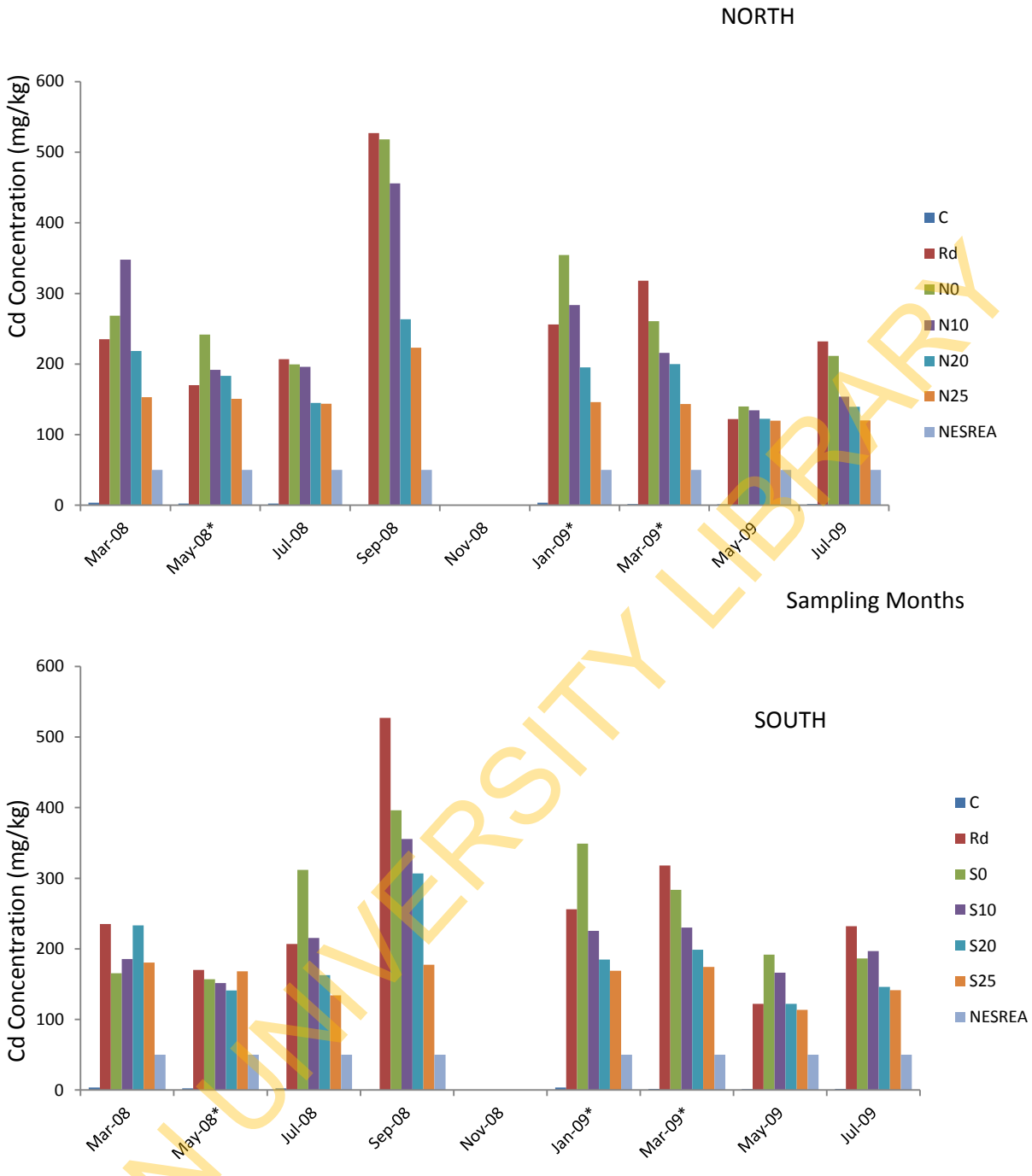


Figure 4.4 Bimonthly Concentration of Cadmium in Soils of Waste Dumpsite (Rd), North and South Samples

Key:

Each bar	sampling months		Rd	waste dumpsite sample	N	North
successive colors	collection points' Cadmium content		C	Control	S	South

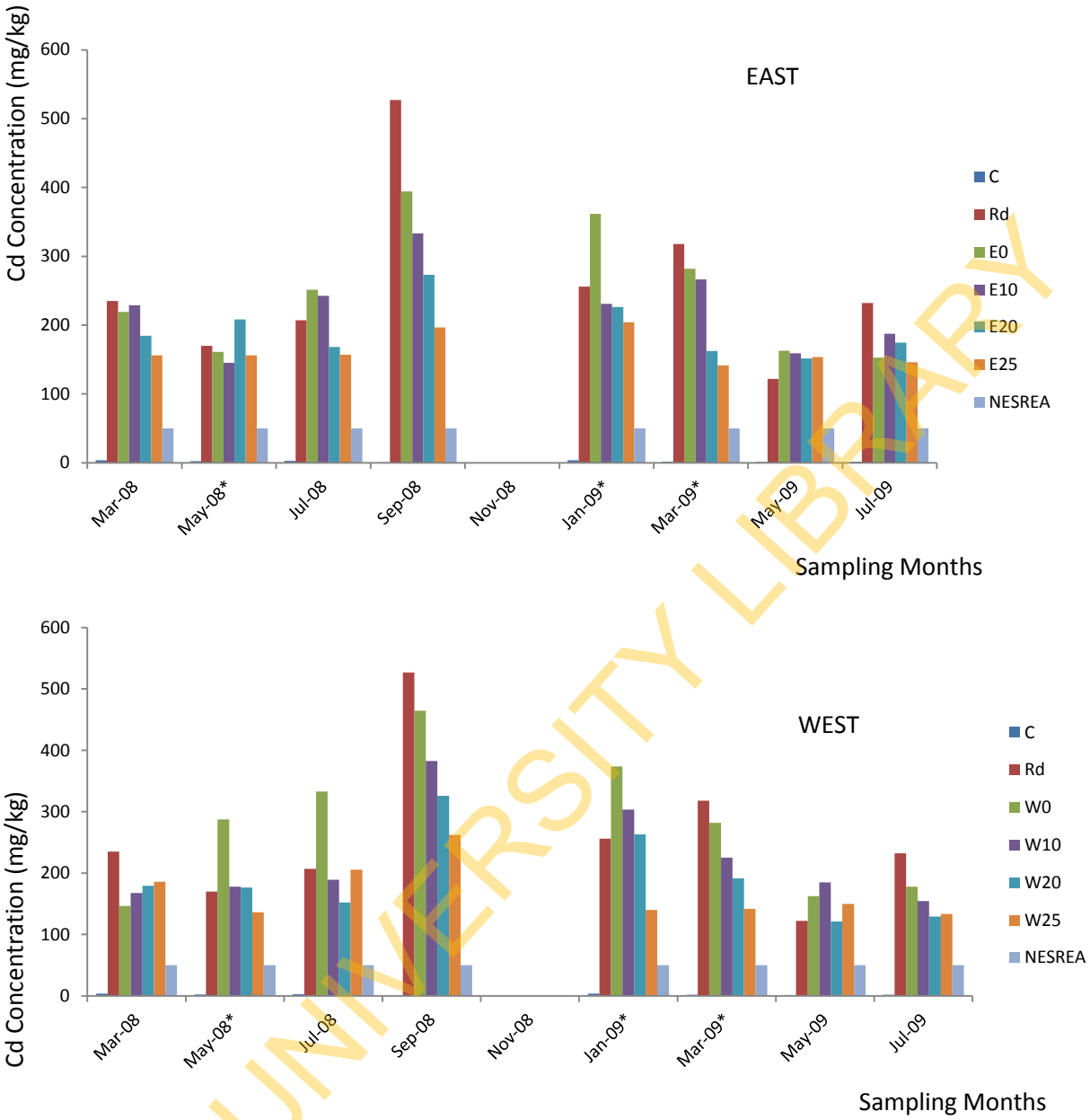


Figure 4.5 Bimonthly Concentration of Cadmium in Soils of Waste Dumpsite (Rd), East and West Samples

Key:

Each bar	sampling months	Rd	waste dumpsite sample	E	East
successive colors	collection points' Cadmium content	C	Control	W	West

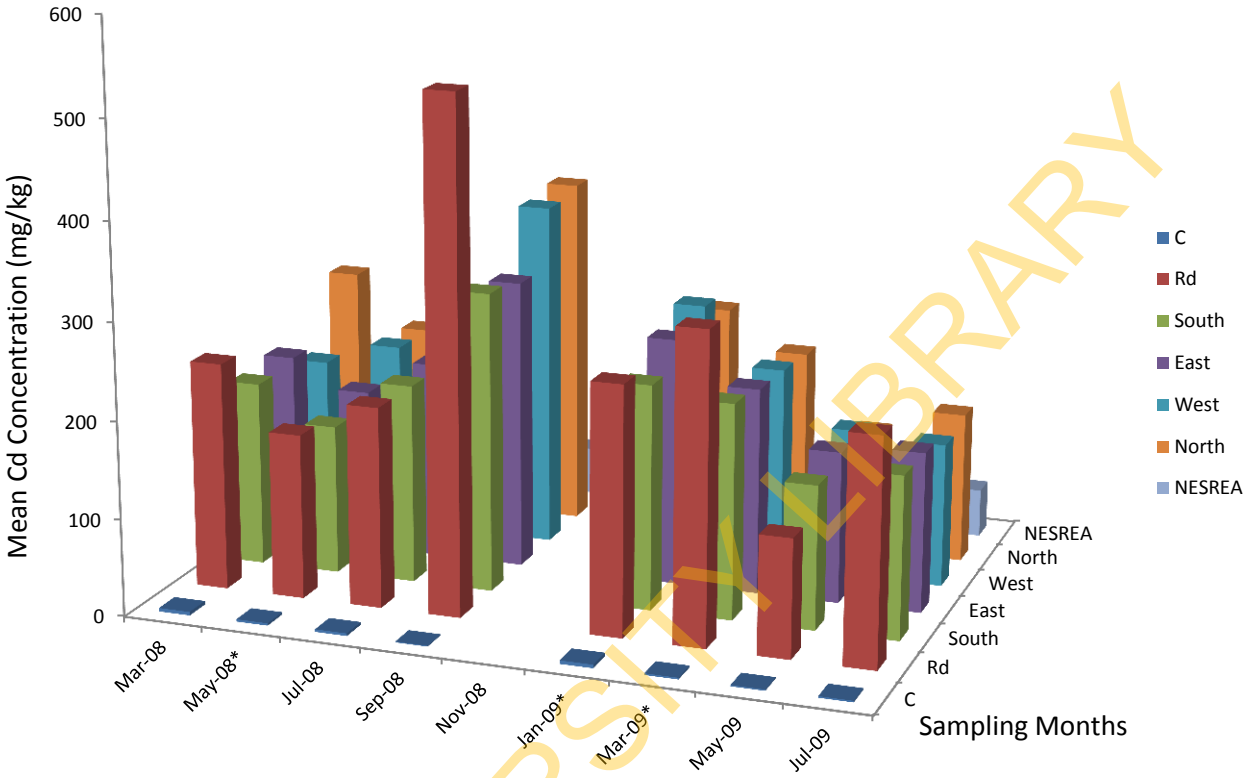


Figure 4.6 Mean Bimonthly Cadmium Concentrations in Soils of Ori-Ile Waste Dumpsite and Surrounding Gradient Points

Key:

Each bar	Mean cadmium concentration across distance in each gradient points
C	Control
Rd	Random waste dumpsite samples
Months with *	significant at p= 0.05

dumpsite ranged from 133.3 mg/kg in July 2009 to 262.3 mg/kg in September 2008 with a mean and standard deviation of 169.4±45.7 mg/kg (Figure 4.5).

Cadmium concentrations in the topsoil of the control site ranged from 0.8 mg/kg in September 2008 to 3.7 mg/kg in March 2008 and January 2009 with a mean and standard deviation of 2.2±1.1 mg/kg (Figure 4.4 and 4.5).

The ANOVA results showed that the differences in mean values for the sampling months within the study site, were not significant at p=0.05 except May 2008, January 2009 and March 2009 (Figure 4.6).

4.1.2.2 Variation with Distance in Cadmium Concentration along the Gradient Points

The results showed decline in mean cadmium concentration along the North (N), South (S), East (E) and West (W) gradient points as the distance increases from 0 m to 25 m from the edge of the waste dumpsite. Overall, there was a similar pattern of cadmium distribution along the distances 0 m to 25 m in each of the gradient points and it follows the order 0 m > 10 m > 20 m > 25 m (Figure 4.4 and 4.5).

The highest mean cadmium concentration in all the gradient points was at 0 m, which is at the edge of the waste dumpsite. However, only mean cadmium concentration of distances N0m and W0m were as high as that of the random sample of the waste dumpsite (Rd) (Figure 4.4 and 4.5).

4.1.3 Iron

4.1.3.1 Bimonthly Variation in Iron Concentration of Random Waste dumpsite Sample, Each Gradient Point Distance and Control

Iron concentrations in the topsoil samples collected from the waste dumpsite (random sample) ranged from 7440.0 mg/kg in May 2009 to 8640.0 mg/kg in May 2009 with a mean and standard deviation of 7910.0±791.5 mg/kg (Figure 4.7 and 4.8). Iron concentrations in the topsoil of distance 0 m along the North gradient point direction from the edge of the waste dumpsite ranged from 6936.7 mg/kg in July 2009 to 8873.3 mg/kg in January 2009 with a mean and standard deviation of 7840.8±728.9 mg/kg.

Iron concentrations in the topsoil of distance 10 m along the North gradient point direction from the edge of the waste dumpsite ranged from 7190.0 mg/kg in September 2008 to 9260.0 mg/kg in January 2009 with a mean and standard deviation of 8346.7±642.0 mg/kg. Iron concentrations in the topsoil of distance 20 m along the North gradient point direction from the edge of the waste dumpsite ranged from 6073.3 mg/kg in May 2009 to 8456.7 mg/kg in March 2009 with a mean and standard deviation of 7443.8±751.1 mg/kg. Iron concentrations in the topsoil of distance 25 m along the North gradient point direction from the edge of the waste dumpsite ranged from 6400.0 mg/kg in July 2009 to 8460.0 mg/kg in March 2008 with a mean and standard deviation of 7585.4±613.6 mg/kg (Figure 4.7).

Iron concentrations in the topsoil of distance 0 m along the South gradient point direction from the edge of the waste dumpsite ranged from 7630.0 mg/kg in March 2008 to 8843.3 mg/kg in July 2008 with a mean and standard deviation of 8189.6±471.2 mg/kg. Iron concentrations in the topsoil of distance 10 m along the South gradient point direction from the edge of the waste dumpsite ranged from 6443.3 mg/kg in July 2009 to 8056.7 mg/kg in March 2009 with a mean and standard deviation of 7479.2±561.3 mg/kg. Iron concentrations in the topsoil of distance 20 m along the South gradient point direction from the edge of the waste dumpsite ranged from 6790.0 mg/kg in May 2009 to 8693.3 mg/kg in May 2008 with a mean and standard deviation of 7765.4±626.1 mg/kg. Iron concentrations in the topsoil of distance 25 m along the South gradient point direction from the edge of the waste dumpsite ranged from 6603.3 mg/kg in July 2009 to 7943.3 mg/kg in July 2008 with a mean and standard deviation of 7466.2±538.2 mg/kg (Figure 4.7).

Iron concentrations in the topsoil of distance 0 m along the East gradient point direction from the edge of the waste dumpsite ranged from 7023.3 mg/kg in May 2009 to 9250.0 mg/kg in September 2008 with a mean and standard deviation of 8130.0±808.4 mg/kg. Iron concentrations in the topsoil of distance 10 m along the East gradient point direction from the edge of the waste dumpsite ranged from 6756.7 mg/kg in March 2008 to 9090.0 mg/kg in January 2009 with a mean and standard deviation of 7805.4±808.7 mg/kg. Iron concentrations in the topsoil of distance 20 m

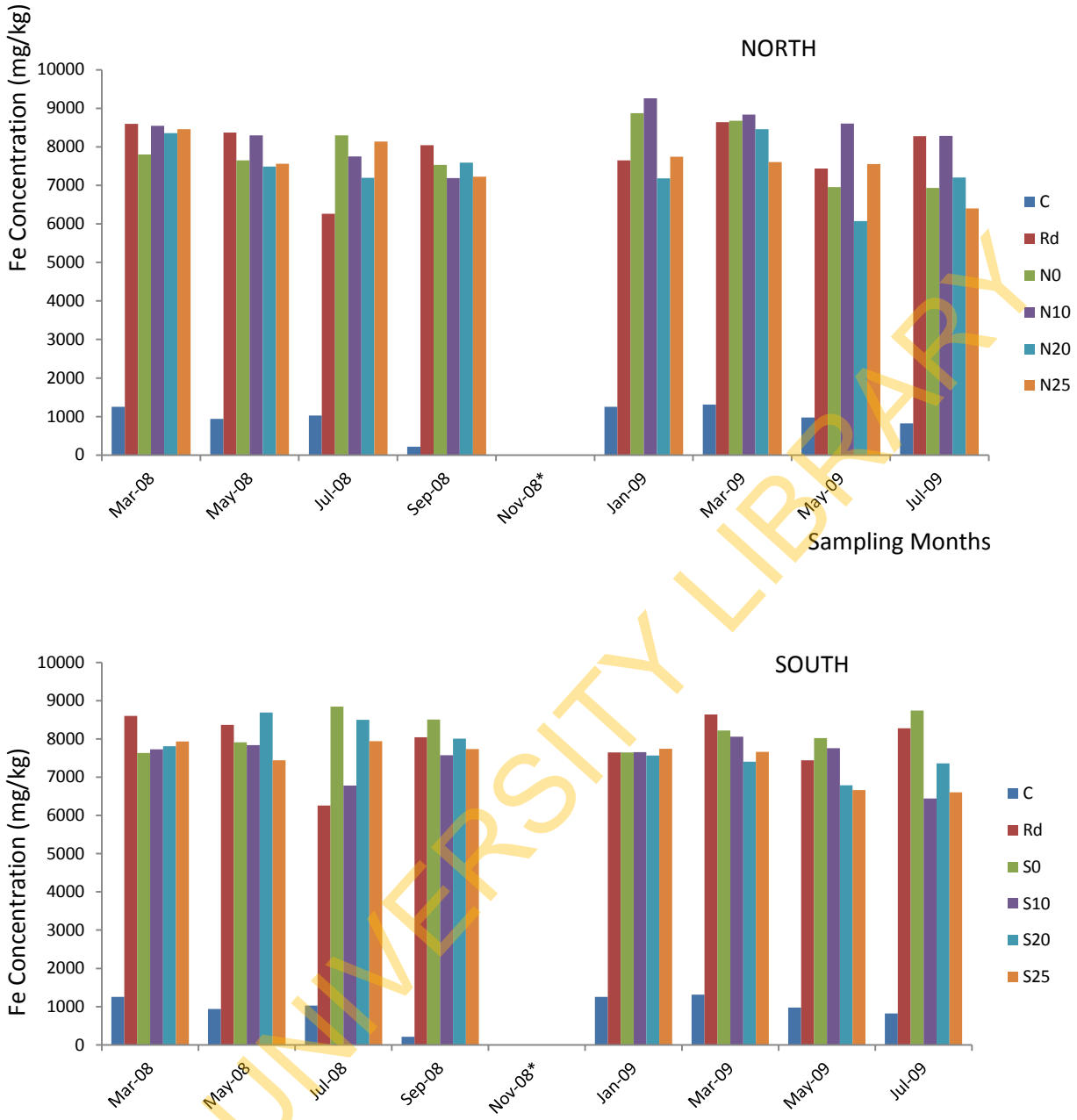


Figure 4.7 Bimonthly Concentration of Iron in Soils of Waste Dumpsite (Rd), North and South Samples

Key:

Each bar	sampling months	Rd	waste dumpsite sample	N	North
successive colors	collection points' Iron content	C	Control	S	South

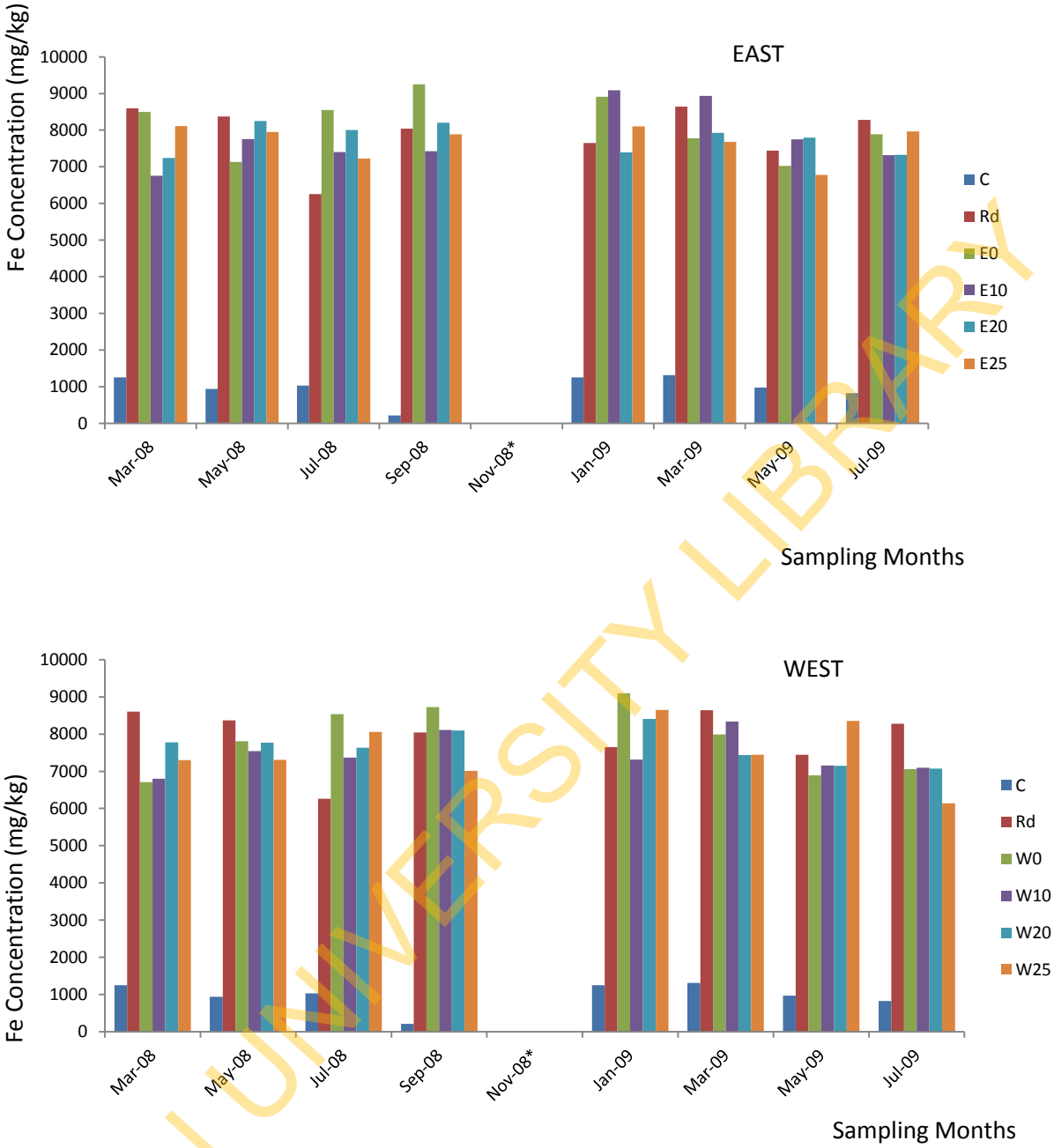


Figure 4.8 Bimonthly Concentration of Iron In Soils of Waste Dumpsite (Rd), East and West Samples

Key:

Each bar	sampling months	Rd	waste dumpsite sample	E	East
successive colors	collection points' Iron content	C	Control	W	West

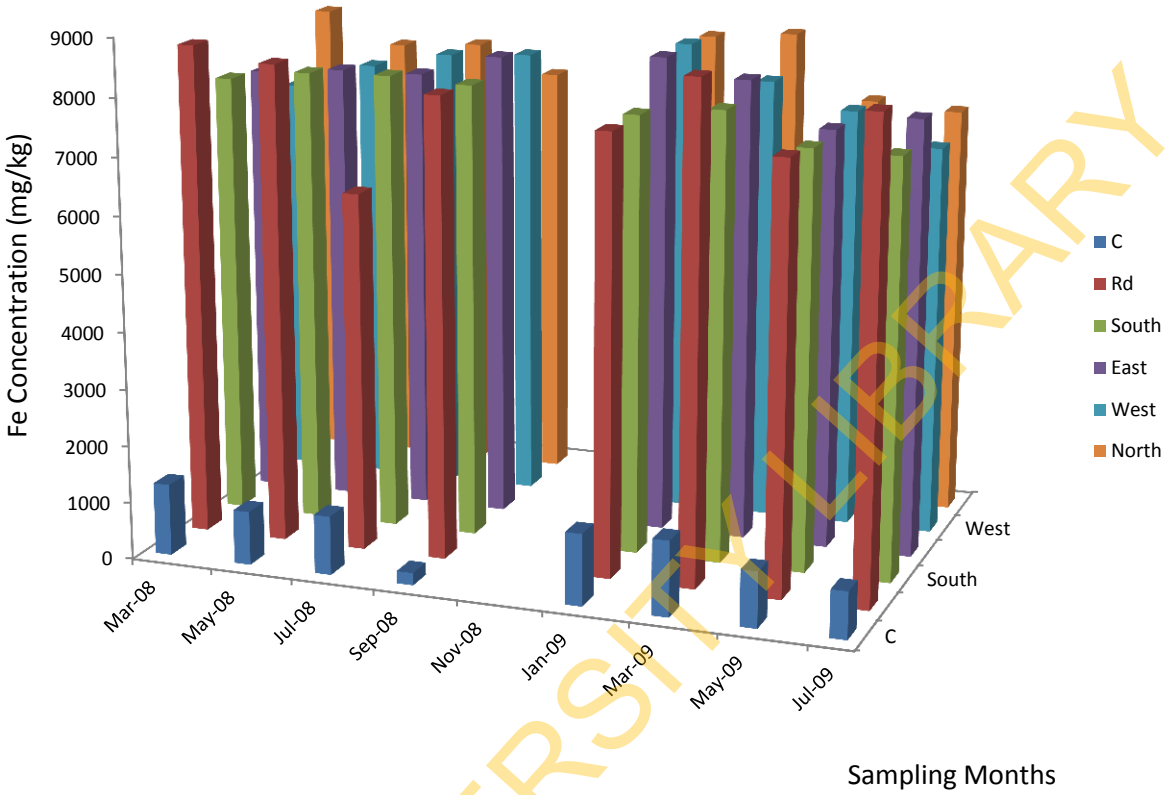


Figure 4.9 Mean Bimonthly Iron Concentrations in Soils of Ori-Ile Waste Dumpsite and Surrounding Gradient Points

Key:

Each bar	Mean Iron concentration across distance in each gradient points
C	Control
Rd	Random waste dumpsite samples

All sampling months are not significant at p= 0.05

along the East gradient point direction from the edge of the waste dumpsite ranged from 7243.3 mg/kg in March 2008 to 8250.0 mg/kg in May 2008 with a mean and standard deviation of 7769.6±398.4 mg/kg. Iron concentrations in the topsoil of distance 25 m along the East gradient point direction from the edge of the waste dumpsite ranged from 6780.0 mg/kg in May 2009 to 8110.0 mg/kg in March 2009 with a mean and standard deviation of 7712.9±473.8 mg/kg (Figure 4.8).

Iron concentrations in the topsoil of distance 0 m along the West gradient point direction from the edge of the waste dumpsite ranged from 6710.0 mg/kg in March 2008 to 9093.3 mg/kg in January 2009 with a mean and standard deviation of 7851.3±898.7 mg/kg. Iron concentrations in the topsoil of distance 10 m along the West gradient point direction from the edge of the waste dumpsite ranged from 6800.0 mg/kg in March 2008 to 8336.7 mg/kg in March 2009 with a mean and standard deviation of 7465.8±520.0 mg/kg. Iron concentrations in the topsoil of distance 20 m along the West gradient point direction from the edge of the waste dumpsite ranged from 7073.3 mg/kg in July 2009 to 8406.7 mg/kg in January 2009 with a mean and standard deviation of 7666.3±452.1 mg/kg. Iron concentrations in the topsoil of distance 25 m along the West gradient point direction from the edge of the waste dumpsite ranged from 6136.7 mg/kg in July 2009 to 8646.7 mg/kg in January 2009 with a mean and standard deviation of 7531.3±804.1 mg/kg (Figure 4.8).

Iron concentrations in the topsoil of the control site ranged from 825.0 mg/kg in July 2009 to 1315.0 mg/kg in March 2009 with a mean and standard deviation of 976.3±207.2 mg/kg (Figure 4.7 and 4.8).

The ANOVA results showed that the differences in mean values for all the sampling months within the study site, were not significant at p=0.05 (Figure 4.9).

4.1.3.2 Variation with Distance in Iron Concentration along the Gradient Points

The results showed decline in mean iron concentration along the East (E) gradient point as the distance increases from 0 m to 25 m from the edge of the waste dumpsite. Along the North (N) gradient point, the result revealed increase in mean iron concentration from distance 0 m to 10 m and 20 m to 25 m. But, the result showed a decline from distance 10 m to 20 m. Along the South (S) and West (W) gradient

points, the result showed decline in mean iron concentration from distance 0 m to 10 m and 20 m to 25 m; but, the result revealed an increase from distance 10 m to 20 m respectively. Overall, there was a similar pattern of iron distribution along the South (S) and West (W) gradient points only while the East and North gradient points had different pattern of iron distributions (Figure 4.7 and 4.8).

The highest mean iron concentration in all the gradient points was at distance 0 m, which is at the edge of the waste dumpsite, along the East, South and West gradient points.

4.1.4 Contamination Factors and Pollution Load Indices of the Topsoil Samples from Ori-Ile Waste Dumpsite and Surrounding Gradient Points

The calculated contamination factors (CF) and Pollution Load Index (PLI) for each of lead, cadmium and iron in the topsoil samples from waste dumpsite and the different gradient points along distance 0 m to 25 m revealed the extent of the pollution in the soil by the studied heavy metals.

The random waste dumpsite topsoil samples calculated CF and PLI respectively for lead was 27.22 and 9.45; cadmium was 117.27 and 15.38; iron was 8.10 and 6.31 (Figure 4.10). The North gradient point's topsoil samples calculated CF and PLI respectively for lead was 25.56 and 9.26; cadmium was 97.18and 14.45; iron was 7.99 and6.28 while that of the South gradient point for lead was 24.60 and 9.14; cadmium was 92.64 and14.22; iron was 7.91 and 6.26 respectively (Figure 4.10). The East gradient point's topsoil samples calculated CF and PLI respectively for lead was 24.81 and 9.16; cadmium was 94.32 and 14.31; iron was 8.05 and 6.30 while that of the West gradient point for lead was 25.35 and 9.23; cadmium was 98.09 and14.50; iron was 7.81 and 6.24 respectively (Figure 4.10).

Overall, all the soil CF and PLIs values were significantly very high and the random waste dumpsite topsoil had the highest CF than all the other studied areas (Figure 4.10). all the calculated soil PLI values were above one and this further indicated significant heavy metal accumulation and pollution in soil from the test site.

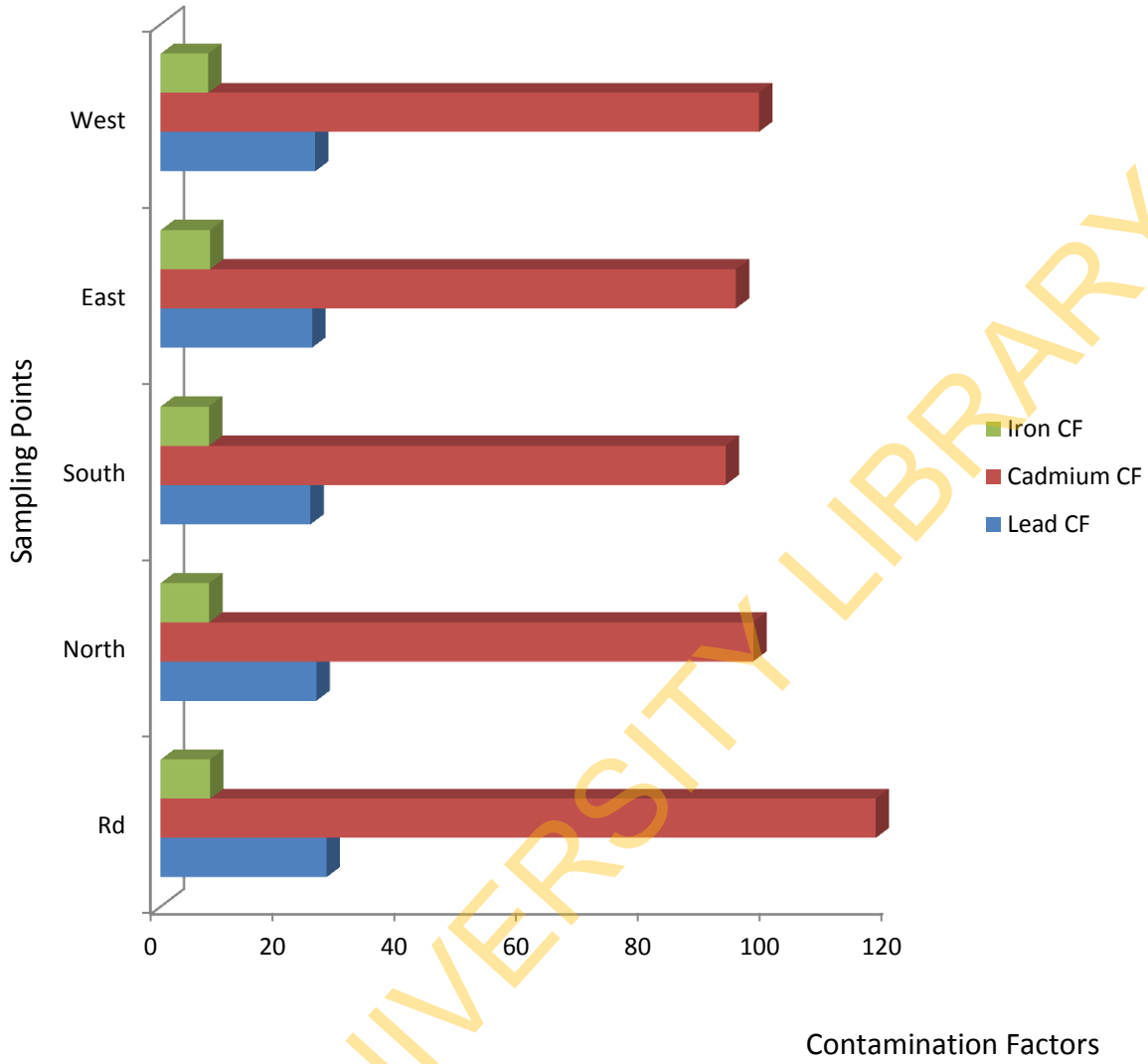


Figure 4.10 Contamination Factors of Soils of Ori-Ile Waste Dumpsite and Surrounding Gradient Points

Key:

Each bar	Calculated contamination factors (CF) for lead, cadmium and iron
Rd	Waste dumpsite samples

CF < 1 = low contamination factor; 1 < CF < 3 = moderate contamination factor

3 < CF < 6 = considerable contamination factor; CF > 6 = very high contamination factor

4.2 Physical and Chemical Parameters of the Soil Samples

4.2.1 Soil pH

The pH of topsoil of the waste dumpsite ranged from 4.00 in May 2008 to 5.76 in September 2008 with a mean ± standard deviation of 5.20±0.66. The pH of topsoil of the North gradient point ranged from 4.07 in May 2008 to 6.06 in May 2009 with a mean ± standard deviation of 5.38±0.75 while that of the South gradient point ranged from 4.09 in May 2008 to 6.10 in March 2009 with a mean ± standard deviation of 5.23±0.71. The pH of topsoil of the East gradient point ranged from 4.62 in March 2009 to 6.60 in May 2009 with a mean ± standard deviation of 5.35±0.66 while that of the West gradient point ranged from 4.22 in March 2008 to 5.68 in January 2009 with a mean ± standard deviation of 5.31±0.68 (Figure 4.11).

The topsoil of the control site had a pH that ranged from 6.02 in May 2008 to 6.75 in January 2009 with a mean and standard deviation of 6.58±0.22. There were no significant differences (p=0.05) between the pH of the waste dumpsite and those of the surrounding gradient points; but these were significant different from the pH of the control (Figure 4.11). Mean with similar letters are not significantly different at p=0.05.

4.2.2 Soil Organic Matter

The results showed that the soil organic matter content of the random dumpsite sample (Rd) was significantly lower (p=0.05) than those obtained in any of the gradient points (0 m – 25 m) and control. The organic matter content of the topsoil of the waste dumpsite ranged from 0.79% in May 2008 to 2.92% in July 2009 with a mean ± standard deviation of 1.73±1.34 %. The organic matter content of the topsoil of the North gradient point ranged from 1.70% in May 2008 to 2.46% in July 2009 with a mean ± standard deviation of 2.13±1.31 % while that of the South gradient point ranged from 1.55% in July 2008 to 2.80% in July 2009 with a mean ± standard deviation of 2.08±1.26 %. The organic matter content of the topsoil of the East gradient point ranged from 0.73% in May 2008 to 2.67% in July 2009 with a mean ± standard deviation of 2.24±1.17 % while that of the West gradient point ranged from 1.48% in May 2008 to 2.79% in July 2008 with a mean ± standard deviation of

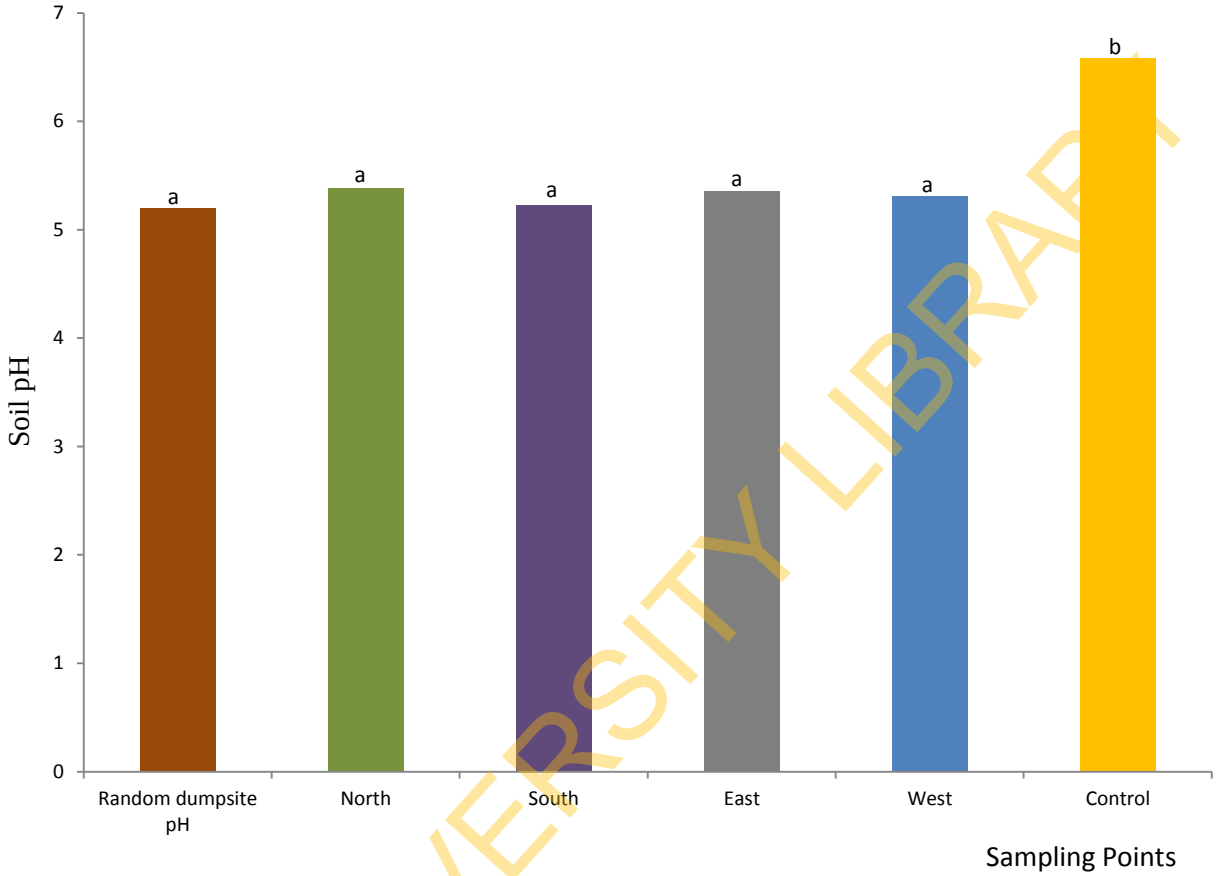


Figure 4.11 Mean pH of Soils of Ori-Ile Waste Dumpsite and Surrounding Areas

Key: Each bar represent soil pH; colors represents collection points

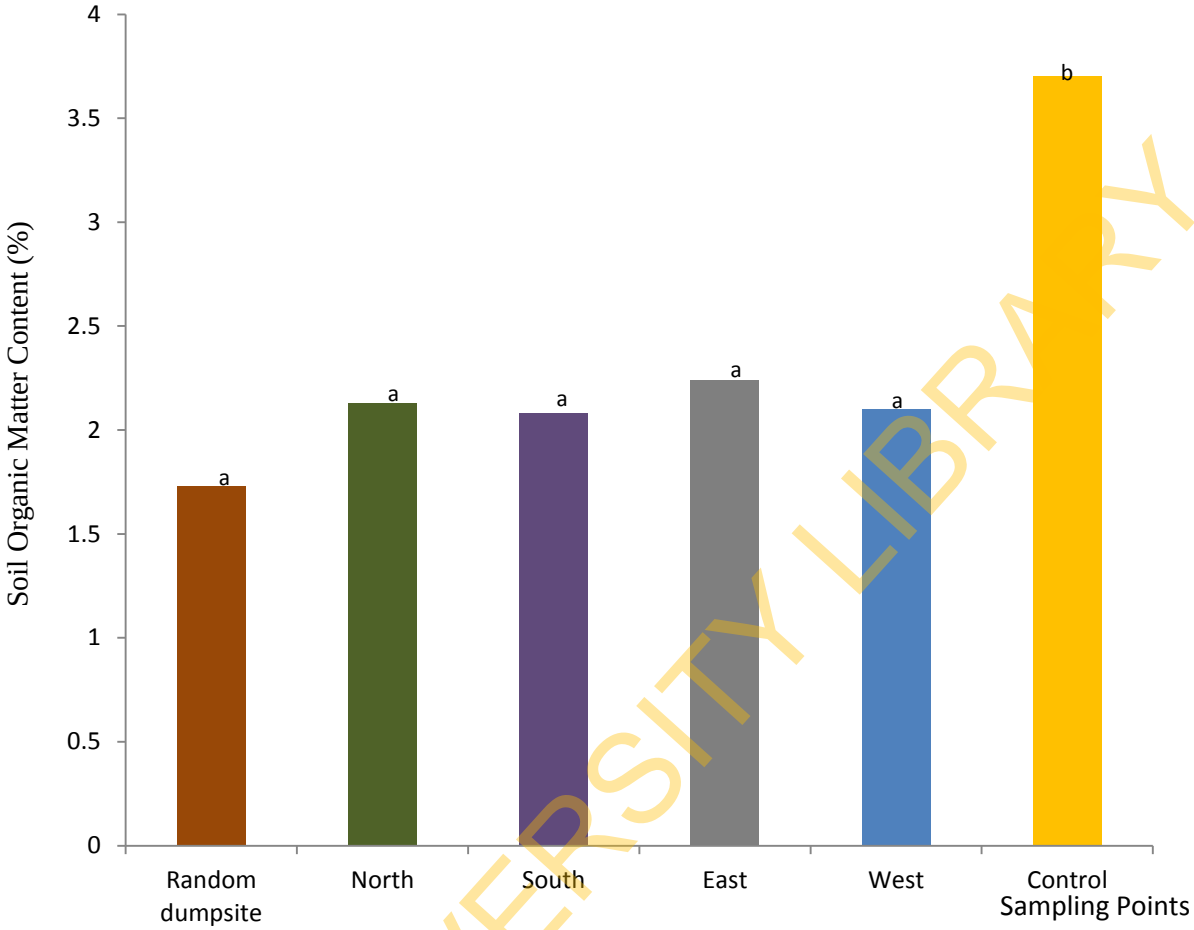


Figure 4.12 Mean Organic Matter Content of Soils from Ori-Ile Waste Dumpsite and Surrounding Areas

Key: Each bar represent soil organic matter content; colors represents collection points

2.10±1.40 % (Figure 4.12). Mean with similar letters are not significantly different at p=0.05.

The organic matter content of the topsoil of the control site ranged from 2.93% in May 2008 to 3.95% in March 2009 with a mean and standard deviation of 3.70±1.72 %. There were no significant difference (p=0.05) between the organic matter of the waste dumpsite and those of the gradient points (Figure 4.12).

4.2.3 Soil Organic Carbon

The results showed that the soil organic carbon content of the random dumpsite sample (Rd) was significantly lower (p=0.05) than those obtained in any of the gradient points (0 m – 25 m) and control. The organic carbon content of the topsoil of the waste dumpsite ranged from 0.84% in September 2008 to 1.65% in May 2009 with a mean ± standard deviation of 1.02±0.76 %. The organic carbon content of the topsoil of the North gradient point ranged from 0.97% in July 2008 to 1.79% in May 2009 with a mean ± standard deviation of 1.24±0.76 % while that of the South gradient point ranged from 0.85% in May 2008 to 1.68% in May 2009 with a mean ± standard deviation of 1.21±0.73 %. The organic carbon content of the topsoil of the East gradient point ranged from 0.55% in July 2008 to 2.11% in September 2008 with a mean ± standard deviation of 1.31±0.68 % while that of the West gradient point ranged from 0.95% in May 2008 to 1.48% in January 2009 with a mean ± standard deviation of 1.22±0.82 % (Figure 4.13).

The organic carbon content of the topsoil of the control site ranged from 2.11% in March 2009 to 2.67% in May 2008 with a mean and standard deviation of 2.15±0.93 %. There were no significant difference (p=0.05) between the organic carbon of the waste dumpsite and those of the gradient points (Figure 4.13). Mean with similar letters are not significantly different at p=0.05.

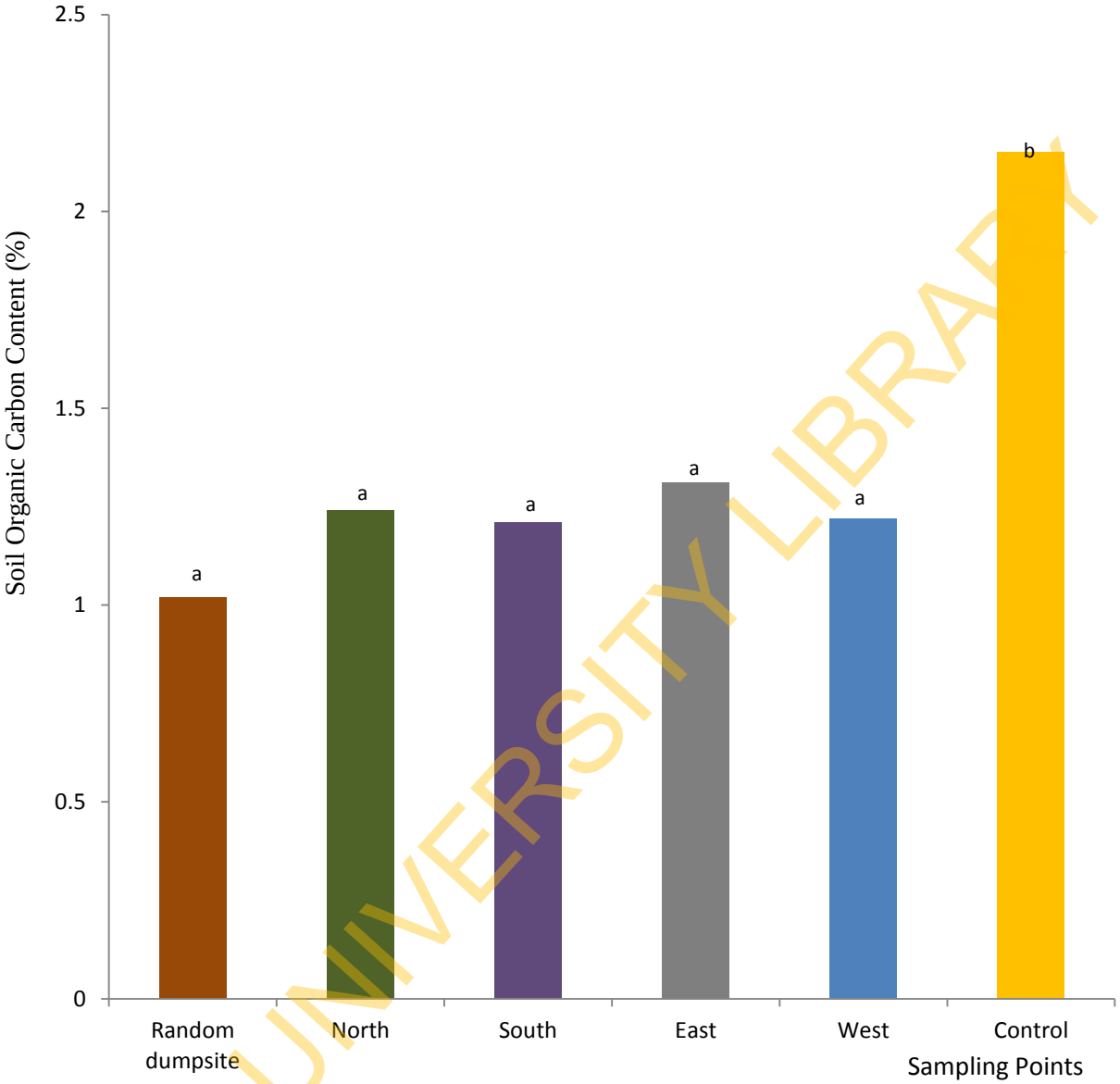


Figure 4.13 Mean Organic Carbon Content of Soils from Ori-Ile Waste Dumpsite and Surrounding Areas

Key: Each bar represent soil organic carbon content; colors represents collection points

4.2.4 Cations Exchange Capacity

Cations exchange capacity in the topsoil samples of the random waste dumpsite samples ranged from 164cmol/kg in May 2008 to 231 cmol/kg in July 2009 with a mean ± standard deviation of 179.0±44.0 cmol/kg. The cations exchange capacity in the topsoil of the North gradient point ranged from 146 cmol/kg in January 2009 to 215 cmol/kg in July 2008 with a mean ± standard deviation of 187.0±38.0 cmol/kg while that of the South gradient point ranged from 162 cmol/kg in July 2009 to 202 cmol/kg in March 2008 with a mean± standard deviation of 183.0±46.0 cmol/kg. The cations exchange capacity in the topsoil of the East gradient point ranged from 173 cmol/kg in May 2009 to 208 cmol/kg in September 2008 with a mean ± standard deviation of 181.0±45.0 cmol/kg while that of the West gradient point ranged from 134 cmol/kg in March 2009 to 213 cmol/kg in May 2008 with a 199.0±42.0 cmol/kg. The cations exchange capacity in the topsoil of the control site ranged from 85 cmol/kg in May 2009 to 114 cmol/kg in March 2009 with a mean and standard deviation of 92.5±0.36 cmol/kg (Figure 4.14).

Overall, the waste dumpsite R had a lower cation exchange capacity compared to the values obtained from soil sampled along the gradient points around it and the west point around the waste dumpsite had the highest cation exchange capacity (Figure 4.14). There were no significant difference (p=0.05) between the cations exchange capacity of the waste dumpsite and those of the gradient points, but these were significantly different from control (Figure 4.14). Mean with similar letters are not significantly different at p=0.05.

4.2.5 Soil Particle Size Distribution

The results of the particle size distribution in the topsoil samples of the random waste dumpsite indicated that the top soil on the waste dumpsite was predominantly sandy and has significantly reduced amount of silt and clay. The sand particles of the random waste dumpsite topsoil ranged from 61.52% in May 2008 to 69.52% in March 2009 with a mean ± standard deviation of 64.43±14.97 % while that of the silt and clay ranged from 12.92% and 9.56% in May 2008 to 20.92% and 9.56% in March 2009

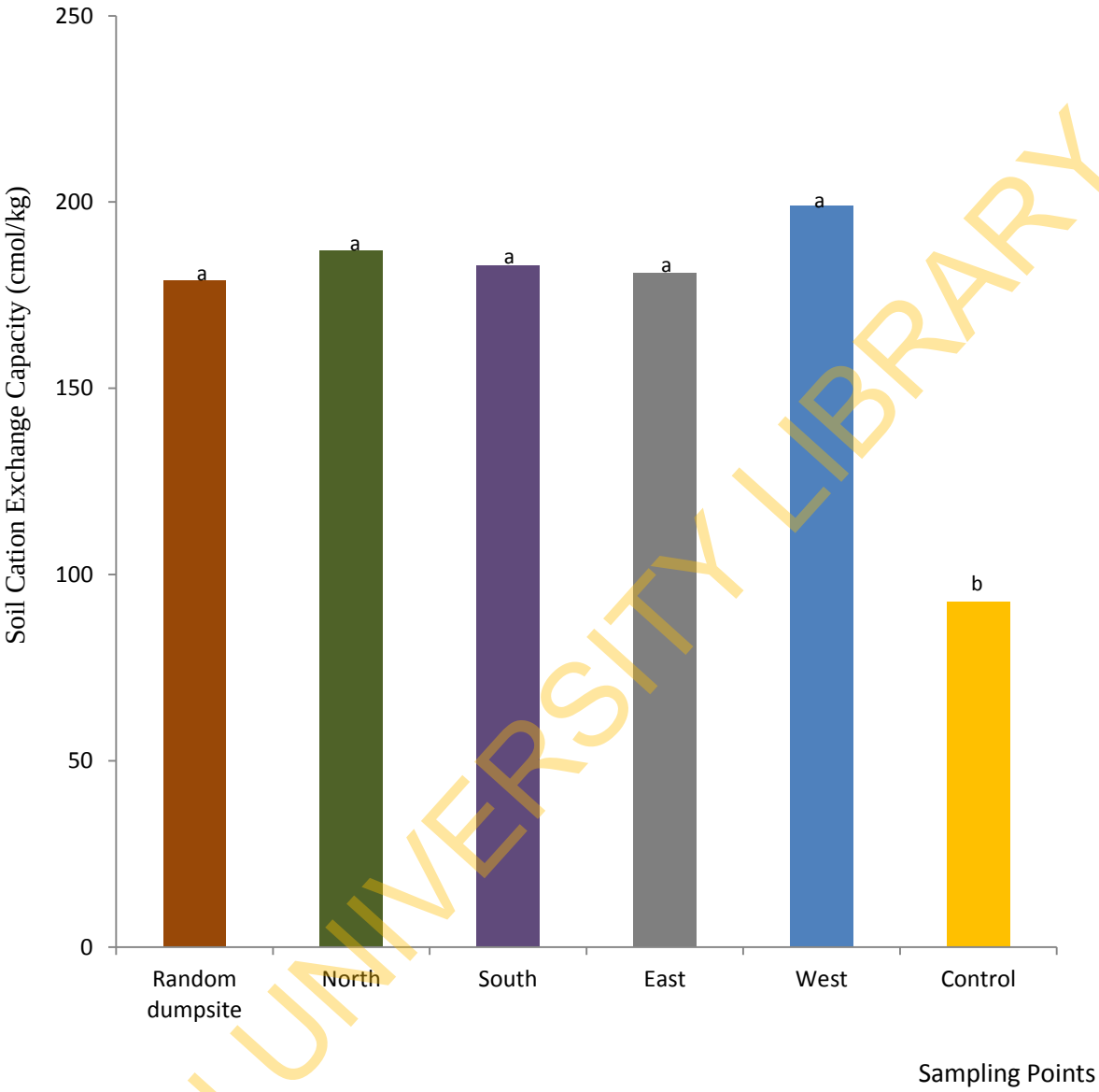


Figure 4.14 Mean Cations Exchange Capacity of Soils from Ori-Ile Waste Dumpsite and Surrounding Areas

Key: Each bar represent soil cation exchange capacity; colors represents collection points

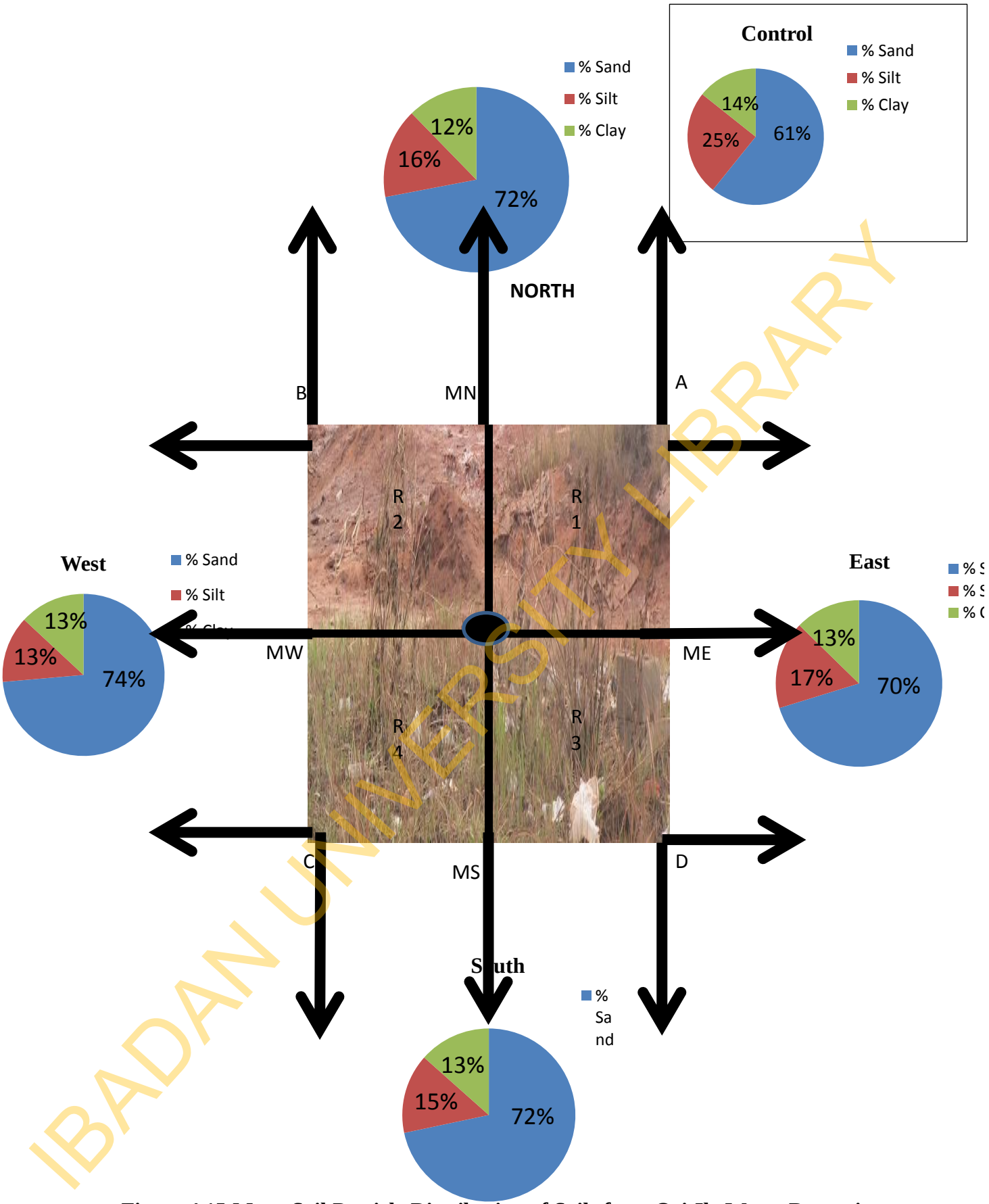


Figure 4.15 Mean Soil Particle Distribution of Soils from Ori-Ile Waste Dumpsite and Surrounding Gradient Points

Key: Each color represents % soil particle content

with a mean ± standard deviation of 21.06±14.46 % and 12.28±2.75 % respectively (Figure 4.15).

The distribution of soil particles along the each of the gradient points North, South, East and West also showed higher percentage composition for the sand particles and reduced amount of silt and clay. The sand particles of the North gradient point topsoil ranged from 55.52% in May 2008 to 82.60% in March 2009 with a mean ± standard deviation of the 72.87±9.64 % while that of the silt and clay ranged from 9.84% and 14.64% in May 2008 to 16.38% and 13.02% in March 2009 with a mean ± standard deviation of 15.90±10.60 % and 12.44±2.67 % respectively. The sand particles of the South gradient point topsoil ranged from 64.60% in July 2008 to 83.52% in May 2009 with a mean ± standard deviation of the 71.08±8.11 % while that of the silt and clay ranged from 1.84% and 17.56% in July 2008 to 4.92% and 11.56% in May 2009 with a mean ± standard deviation of 14.76±8.11 % and 13.32±4.00 % respectively (Figure 4.15).

The sand particles of the East gradient point topsoil ranged from 63.52% in May 2009 to 77.14% in March 2009 with a mean ± standard deviation of 70.43±8.64 % while that of the silt and clay ranged from 16.92% and 13.56% in March 2009 to 14.92% and 13.56% in March 2009 with a mean ± standard deviation of 17.12±8.90 % and 12.72±2.71 % respectively. The sand particles of the West gradient point topsoil ranged from 68.60% in March 2009 to 89.52% in July 2008 with a mean ± standard deviation of 73.76±7.36 % while that of the silt and clay ranged from 6.38% and 15.02% in March 2009 to 0.92% and 9.56% in July 2008 with a mean ± standard deviation of 13.33±9.03 % and 13.10±3.14 % respectively (Figure 4.15). The particle size distribution of the topsoil at the control site also had higher sand content and smaller percentage of silt and clay. The sand particles of the control topsoil ranged from 56.38% in March 2008 to 67.84% in May 2009 with a mean ± standard deviation of the 61.37±7.60 % while that of the silt and clay ranged from 12.19% and 18.45% in March 2009 to 27.21% and 13.53% in March 2009 with a mean ± standard deviation of 25.13±2.03 % and 14.45±4.84 % respectively (Figure 4.15).

The result of the particle size distribution showed that the random waste dumpsite topsoil had a significantly higher amount of silt ($p=0.05$) while the sand and clay content was significantly lower ($p=0.05$) than all the gradient points and control. There

were no significant difference (p=0.05) between the sand and clay particle distribution along the gradient points. However, the silt particle of the East gradient points was significantly higher (p=0.05) than those of the North, South and West gradient points (Figure 4.15).

4.2.6 Soil Permeability

The result of the permeability indicated that the topsoil samples of the random waste dumpsite ranged from 0.33 cm^3/cm^3 in March 2009 to 0.63 $cm^3/cm3$in July 2009 with a mean ± standard deviation of 0.52±0.11 cm^3/cm^3. The topsoil samples of the North gradient point had permeability value that ranged from 0.48 cm^3/cm^3 in March 2009 to 0.63 cm^3/cm^3 in May 2008 with a mean ± standard deviation of 0.51±0.11 cm^3/ cm^3 while that of the South gradient point ranged from 0.48 cm^3/cm^3 in July 2009 to 0.62 cm^3/cm^3 in March 2008 with a mean ± standard deviation of 0.50±0.11 cm^3/cm^3. The topsoil of the East gradient point had permeability value that ranged from 0.48 cm^3/cm^3 in July 2008 to 0.60 cm^3/cm^3 in March 2009 with a mean ± standard deviation of 0.52±0.11 cm^3/cm^3 while that of the West gradient point ranged from 0.44 cm^3/cm^3 in March 2009 to 0.62 cm^3/cm^3 in January 2009 with a mean 0.52±0.10 cm^3/cm^3 (Figure 4.16). The permeability value of the control topsoil ranged from 0.30 cm^3/cm^3 in May 2009 to 0.38 cm^3/cm^3 in March 2008 with a mean ± standard deviation was 0.33±0.19 cm^3/cm^3 (Figure 4.16).

The results of the permeability of the topsoil samples indicated that there were no significant differences (p=0.05) between the waste dumpsite and those of the gradient points but these were significantly different from those of the control (Figure 4.16). Mean with similar letters are not significantly different at p=0.05.

4.2.7 Soil Mineral Content

The result of the soil mineral contents indicated that the topsoil samples of the random waste dumpsite had a soil mineral content that ranged from 0.99 g/cm^3 in May 2008 to 1.55 g/cm^3 in March 2009 with a mean ± standard deviation of 1.31±0.29 g/cm^3. The topsoil samples of the North gradient point had a soil mineral content that ranged from 0.97 g/cm^3 in May 2008 to 1.66 g/cm^3 in March 2009 with a mean ± standard deviation of 1.30±0.29 g/cm^3 while that of the South gradient point ranged from 0.95 g/cm^3 in March 2009 to 1.67 g/cm^3 in July 2008 with a mean ± standard deviation of

1.32±0.28 g/cm^3. The topsoil of the East gradient point had soil mineral content that ranged from 0.95 g/cm^3 in May 2008 to 1.75 g/cm^3 in May 2009 with a mean ± standard deviation of 1.27±0.29 g/cm^3 while that of the West gradient point ranged from 0.97 g/cm^3 in May 2009 to 1.62 g/cm^3 in July 2008 with a mean ± standard deviation of 1.27±0.25 g/cm^3 (Figure 4.17). The soil mineral content of the control topsoil ranged from 1.99 g/cm^3 in July 2008 to 2.85 g/cm^3 in March 2009 with a mean ± standard deviation of 2.76±1.11 g/cm^3 (Figure 4.17).

The results of the soil mineral content of the topsoil samples indicated that there were no significant differences (p=0.05) between the waste dumpsite and those of the gradient points but these were significantly different from those of the control (Figure 4.17). Mean with similar letters are not significantly different at p=0.05.

4.2.8 Percentage Base Saturation

The result of the percentage base saturation indicated that the topsoil samples of the random waste dumpsite had a percentage base saturation that ranged from 92.3 % in March 2009 to 98.9 % in May 2008 with a mean ± standard deviation of 95.65±2.44 %. The topsoil samples of the North gradient point had percentage base saturation that ranged from 92.4 % in March 2009 to 99.2 % in January 2009 with a mean ± standard deviation of 96.24±1.67 % while that of the South gradient point ranged from 90.7 % in May 2008 to 99.1 % in March 2009 with a mean ± standard deviation of 95.73±2.39 %. The topsoil of the East gradient point had percentage base saturation that ranged from 92.6 % in May 2008 to 97.8 % in July 2008 with a mean ± standard deviation of 95.91±1.98 % while that of the West gradient point ranged from 92.5 % in July 2008 to 99.1 % in March 2009 with a mean ± standard deviation of 96.33±1.90 % (Figure 4.18). The percentage base saturation of the control topsoil ranged from 94.8 % in May 2008 to 99.5 % in July 2009 with a mean ± standard deviation of 97.63±1.82 % (Figure 4.18).

The results of the percentage base saturation of the topsoil samples indicated that there were no significant differences (p=0.05) between the waste dumpsite and those of the

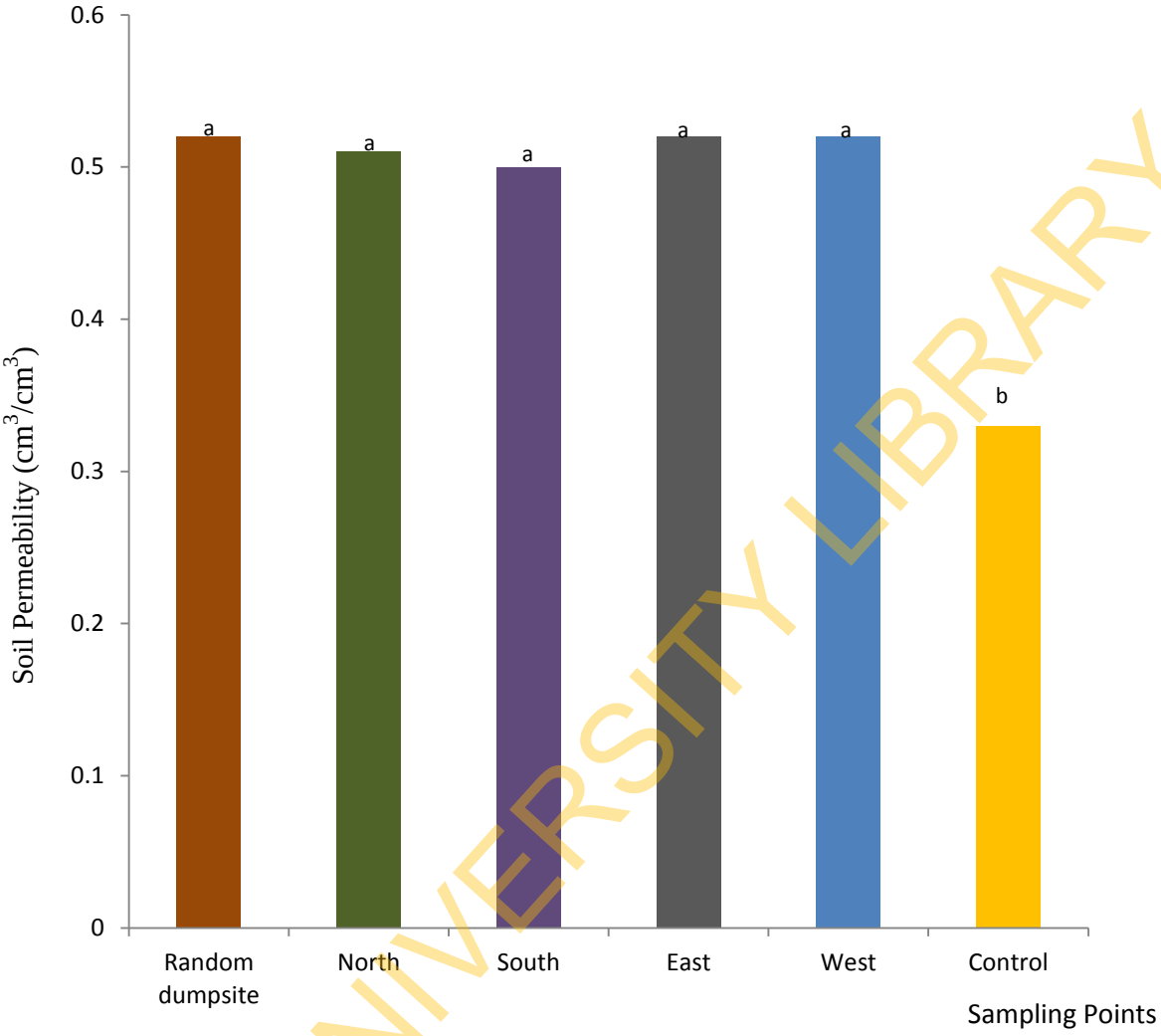


Figure 4.16 Mean Permeability of Soils in Ori-Ile Waste Dumpsite and Surrounding Areas

Each bar represent soil permeability; colors represents collection points

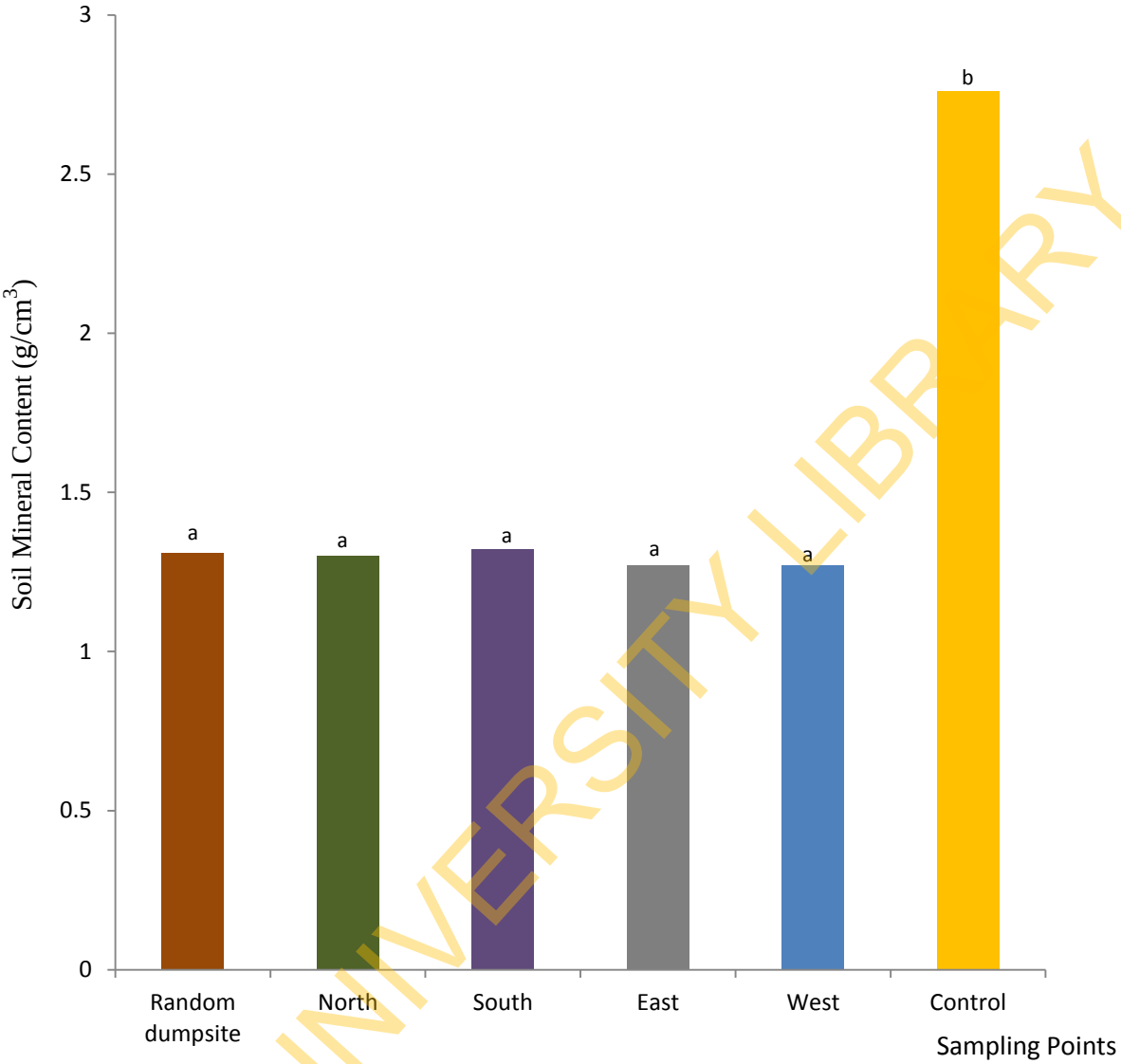


Figure 4.17 Mean Soil Mineral Content of Soils from Ori-Ile Waste Dumpsite and Surrounding Areas

Each bar represent soil mineral content; colors represents collection points

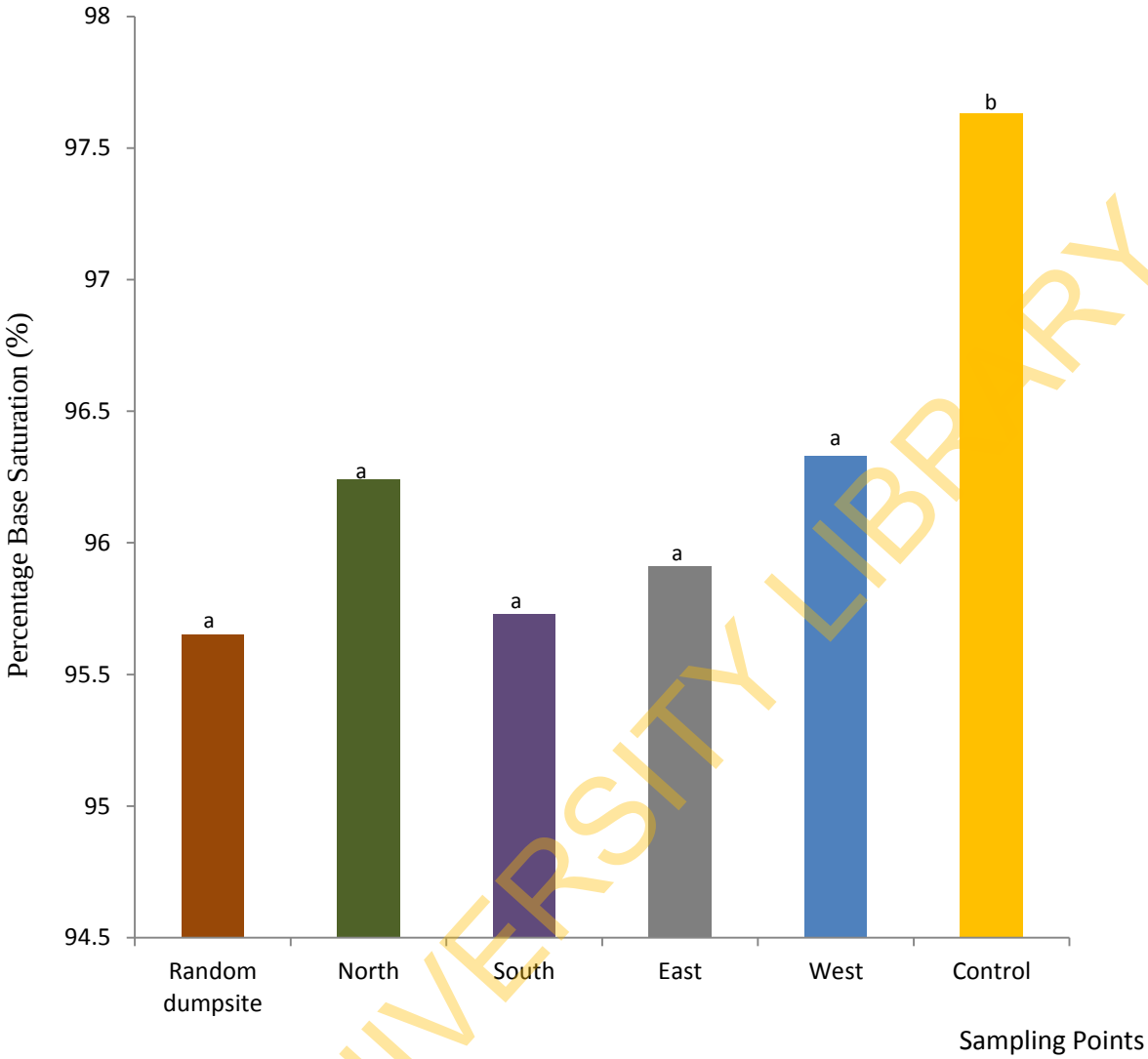


Figure 4.18 Mean Percentage Base Saturation of Soils of Ori-Ile Waste Dumpsite and Surrounding Areas

Each bar represent percentage base saturation; colors represents collection points

gradient points but these were significantly different from those of the control (Figure 4.18). Mean with similar letters are not significantly different at p=0.05.

4.3 Lead, Cadmium and Iron Concentrations in Water Samples

The results of the bimonthly analysis of heavy metals concentrations in the underground and surface water samples from Ori-Ile area along the gradient directions compared to values obtained from control water samples are presented below:

4.3.1 Groundwater Samples

The mean concentration of lead, cadmium and iron in the groundwater within the gradient points {North (N), South (S), East (E) and West (W)} around the waste dumpsite from March 2008 to July 2009 were compared with the standard NESREA values and control. Zero was taken as the concentration where the sample metal level was below detection limit of the instrument.

4.3.1.1 Lead Concentration in Groundwater around Waste Dumpsite and Control

Lead concentrations in the groundwater along the North gradient point from the edge of the waste dumpsite ranged from 0.000 mg/L (March 2008, May 2008, March 2009 and July 2009) to 0.076 mg/L in July 2008 with a mean and standard deviation of 0.017±0.018 mg/L. Lead concentrations in the groundwater along the South gradient point from the edge of the waste dumpsite ranged from 0.000 mg/L (March - May 2008, September 2008- July 2009) to 0.010 mg/L in July 2008 with a mean and standard deviation of 0.001±0.000 mg/L (Figure 4.19).

Lead concentrations in the groundwater along the East gradient point from the edge of the waste dumpsite ranged from 0.000 mg/L (September 2008, January 2009, May 2009 and July 2009) to 0.070 mg/L in March 2008 with a mean and standard deviation of 0.038±0.009 mg/L. Lead concentrations in the groundwater along the West gradient point from the edge of the waste dumpsite ranged from 0.000 mg/L (September 2008, January 2009, May 2009 and July 2009) to 0.045 mg/L in March 2008 with a mean and standard deviation of 0.014±0.001 mg/L. Lead concentration in the groundwater of the control was 0.000 mg/L throughout the period of sampling (Figure 4.19).

The ANOVA results showed that the differences in mean lead concentration in the groundwater samples throughout the sampling months were significant at p=0.05 except July 2008 and May 2009 (Figure 4.19).

4.3.1.2 Cadmium Concentration in Groundwater around Waste Dumpsite and Control

Cadmium concentrations in the groundwater along the North gradient point from the edge of the waste dumpsite ranged from 0.000 mg/L in May 2008 to 0.013 mg/L in July 2009 with a mean and standard deviation of 0.004±0.003 mg/L. Cadmium concentrations in the groundwater along the South gradient point from the edge of the waste dumpsite ranged from 0.000 mg/L (March - May 2008, September 2008, March - July 2009) to 0.002 mg/L in July 2008 with a mean and standard deviation of 0.0003±0.0001 mg/L (Figure 4.20).

Cadmium concentrations in the groundwater along the East gradient point from the edge of the waste dumpsite ranged from 0.003 mg/L in March 2008 to 0.0095 mg/L in September 2008 and July 2009 with a mean and standard deviation of 0.0056±0.001 mg/L. Cadmium concentrations in the groundwater along the West gradient point from the edge of the waste dumpsite ranged from 0.000 mg/L in January 2009 and May 2009 to 0.014 mg/L in May 2008 with a mean and standard deviation of 0.0036±0.001 mg/L. Cadmium concentration in the groundwater of the control was 0.000 mg/L throughout the period of sampling (Figure 4.20). The ANOVA results showed that the differences in mean cadmium concentration in the groundwater samples throughout the sampling months were significant at p=0.05 except March 2008 (Figure 4.20).

4.3.1.3 Iron (Fe) Concentration in Groundwater around Waste Dumpsite and Control

Iron concentrations in the groundwater along the North gradient point from the edge of the waste dumpsite ranged from 0.005 mg/L in May 2008 to 0.09 mg/L in January 2009 with a mean and standard deviation of 0.041±0.023 mg/L. Iron concentrations in the groundwater along the South gradient point from the edge of the waste dumpsite ranged from 0.000 mg/L (March - May 2008, March - July 2009) to 0.045 mg/L in July 2008 with a mean and standard deviation of 0.012±0.0008 mg/L (Figure 4.21).

Iron concentrations in the groundwater along the East gradient point from the edge of the waste dumpsite ranged from 0.000 mg/L in July 2009 to 0.075 mg/L in May 2008 with a mean and standard deviation of 0.034±0.014 mg/L. Iron concentrations in the groundwater along the West gradient point from the edge of the waste dumpsite ranged from 0.000 mg/L in January 2009 and July 2009 to 0.125 mg/L in March 2008 with a mean and standard deviation of 0.044±0.004 mg/L. Iron concentration in the groundwater of the control was 0.000 mg/L throughout the period of sampling (Figure 4.21). The ANOVA results showed that the differences in mean iron concentration in the groundwater samples throughout the sampling months were significant at p=0.05 (Figure 4.21).

4.3.2 Surface Water Samples

The mean concentration of Lead (Pb), Cadmium (Cd) and Iron (Fe) in the surface water in the South gradient point of the waste dumpsite from March 2008 to July 2009 were compared with the standard NESREA values and control. Zero was taken as the concentration where the sample metal level was below detection limit of the instrument. The results of the bimonthly analysis of surface water samples taken from three (3) points (upstream, midstream and downstream) are presented below:

4.3.2.1 Lead (Pb) Concentration in Upstream, Midstream and Downstream of Surface Water in Waste Dumpsite Area and Control

The results obtained showed that lead concentration in the Upstream was 0.000 mg/l throughout the sampling months. The midstream lead concentration ranged from 0.000 mg/l (March 2008 – March 2009) to 0.035 (July 2009) with a mean and standard deviation of 0.024±0.002 mg/l. The downstream lead concentration ranged from 0.000 mg/l (March 2008 – March 2009) to 2.150 (May 2009) with a mean and standard deviation of 0.28±0.01 mg/l. The results obtained showed that lead concentration in the control stream was 0.000 mg/l throughout the sampling months. The ANOVA results

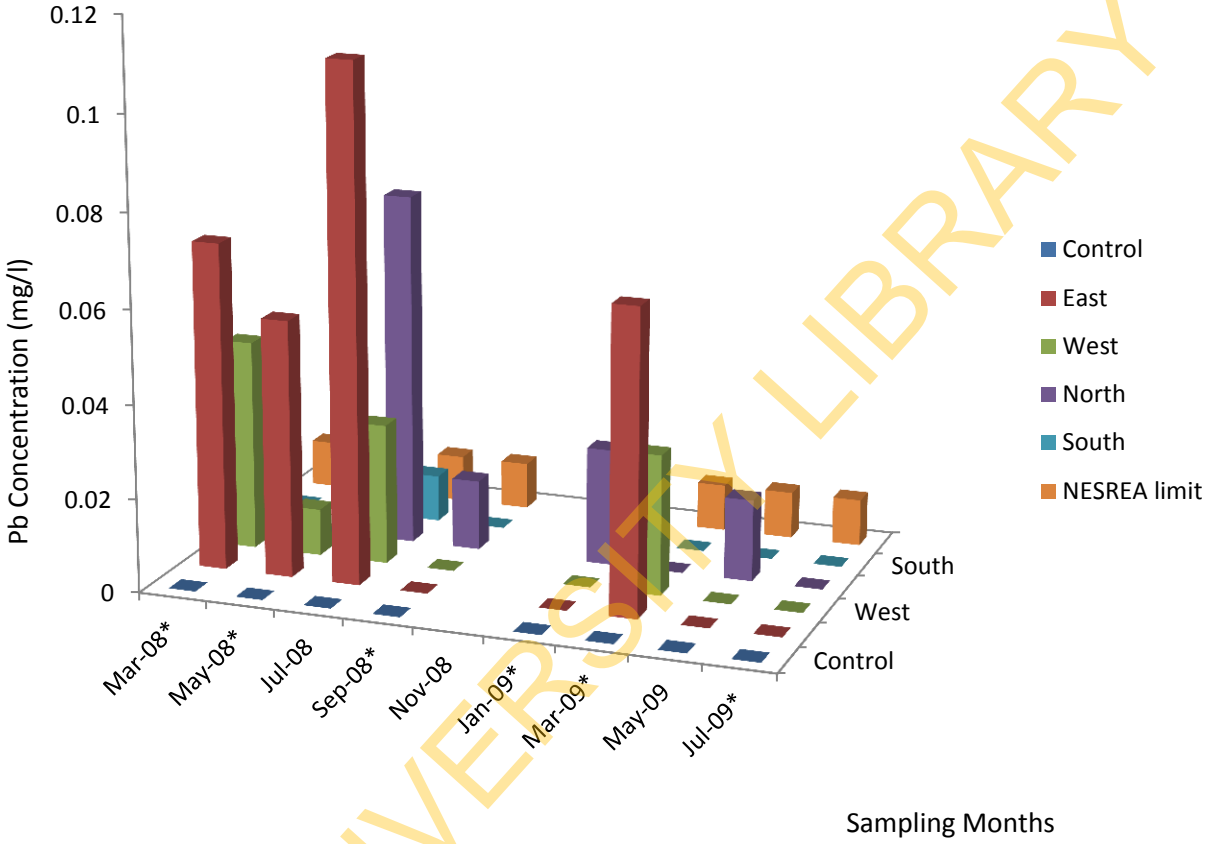


Figure 4.19 Bimonthly Concentration of Lead in Groundwater of Gradient Points around Waste Dumpsite

Months with * are significant at p= 0.05

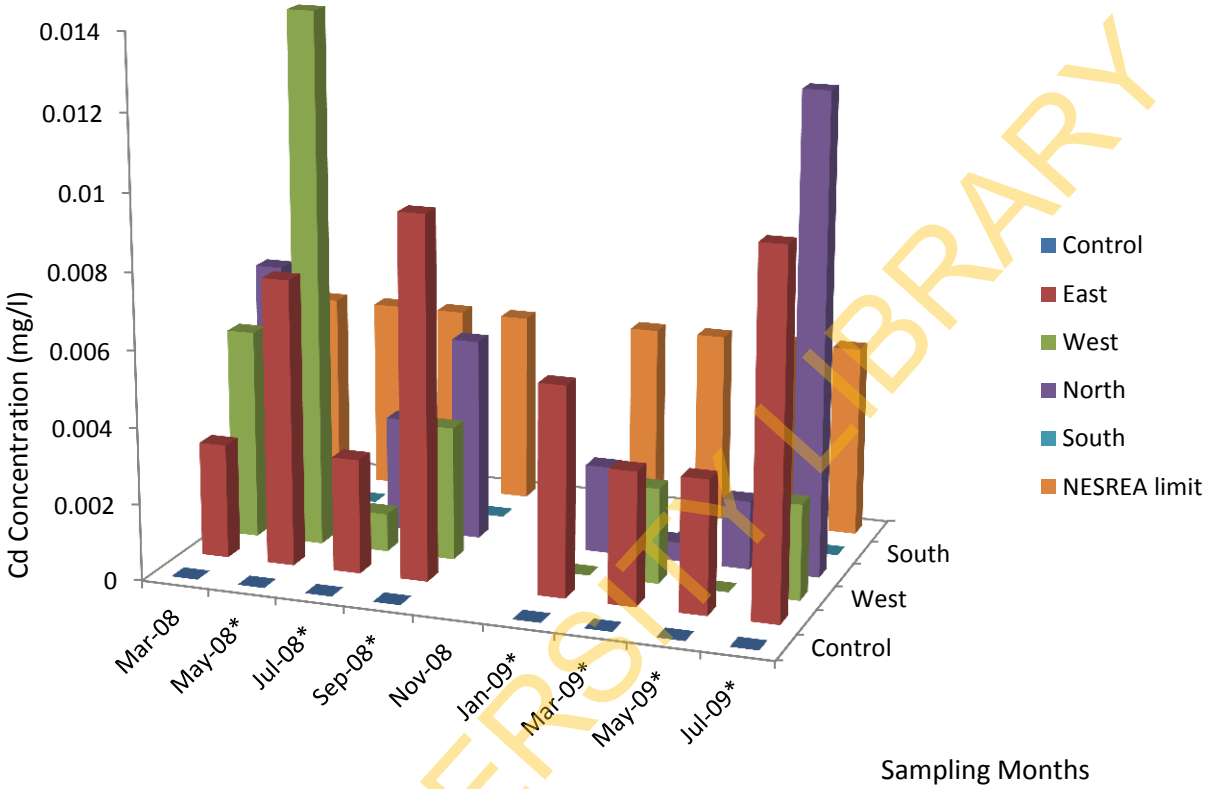


Figure 4.20 Bimonthly Concentration of Cadmium in Groundwater of Gradient Points around Waste Dumpsite

Months with * are significant at p= 0.05

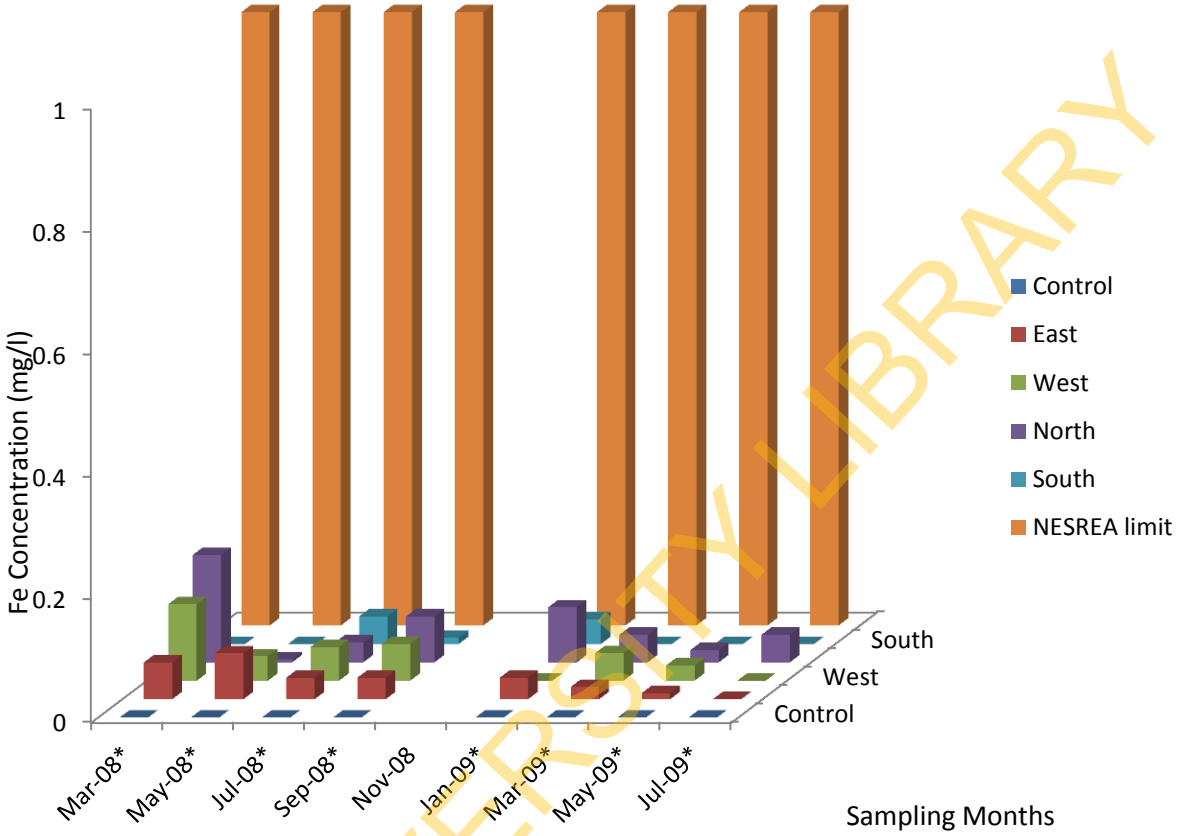


Figure 4.21 Bimonthly Concentration of Iron in Groundwater of Gradient Points around Waste Dumpsite

Months with * are significant at p= 0.05

showed that the differences in mean lead concentration in the surface water samples were significant at p=0.05 only in May 2009 and July 2009 (Figure 4.22).

Overall, downstream had the highest mean lead concentration (0.275mg/l), which was significantly higher than control (p=0.05) and NESREA standard limit (0.01mg/l) while the upstream had the lowest mean lead concentration (0mg/l) and this was the same as control (p=0.05) and significantly lower than NESREA standard limit (0.01mg/l) (Figure 4.22).

4.3.2.2 Cadmium (Cd) Concentration in Upstream, Midstream and Downstream of Surface Water in Waste Dumpsite Area and Control

The results obtained showed that cadmium concentration in the Upstream was 0.000 mg/l throughout the sampling months. The midstream cadmium concentration ranged from 0.000 mg/l (March – July 2008 and March - May 2009) to 0.007 (September 2008) with a mean and standard deviation of 0.002±0.0003 mg/l. The downstream cadmium concentration ranged from 0.000 mg/l (March – May 2008 and March 2009) to 0.171 (May 2009) with a mean and standard deviation of 0.025±0.001 mg/l. The results obtained showed that cadmium concentration in the control stream was 0.000 mg/l throughout the sampling months. The ANOVA results showed that the differences in mean cadmium concentration in the surface water samples were significant at p=0.05 except March 2008, May 2008 and March 2009 (Figure 4.23).

Overall, downstream had the highest mean cadmium concentration (0.025mg/l), which was significantly higher than control (p=0.05) and NESREA standard limit (0.005mg/l) while the upstream had the lowest mean cadmium concentration (0mg/l) and this was the same with control (p=0.05) and significantly lower than NESREA standard limit (0.005mg/l) (Figure 4.23).

4.3.2.3 Iron (Fe) Concentration in Upstream, Midstream and Downstream of Surface Water in Waste Dumpsite Area and Control

The results obtained showed that iron concentration in the Upstream ranged from 0.000 mg/l (March – May 2008, September 2008 and January - March 2009) to 0.055 (May 2009) with a mean and standard deviation of 0.125±0.0018 mg/l. The midstream

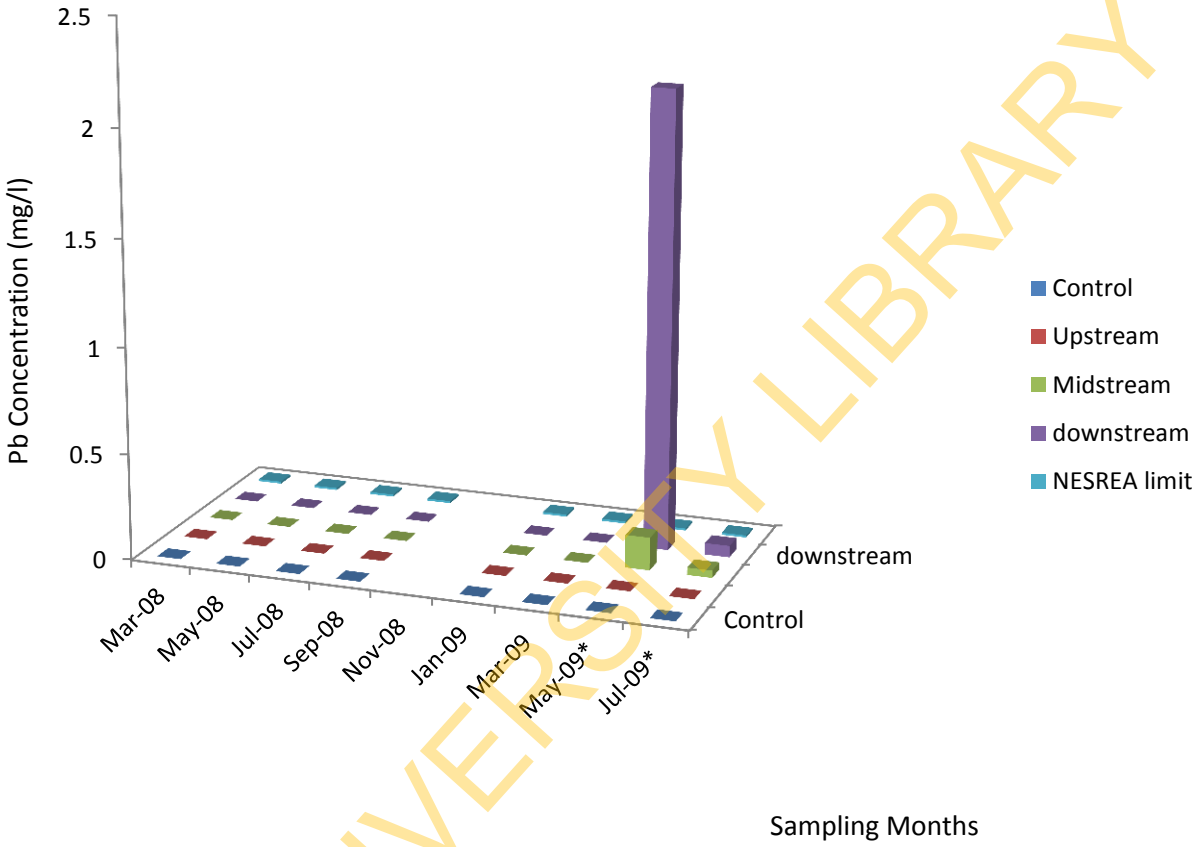


Figure 4.22 Bimonthly Concentration of Lead in Water from Omi Stream

Months with * are significant at p= 0.05

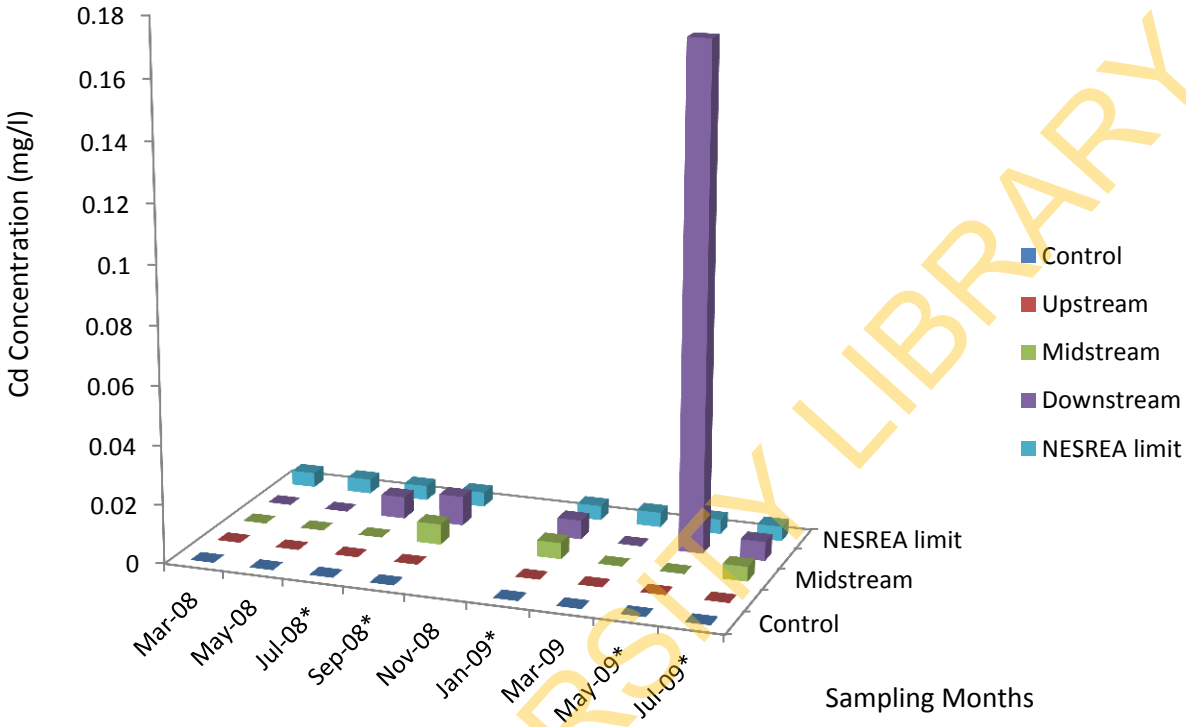


Figure 4.23 Bimonthly Concentration of Cadmium in Water from Omi Stream

Months with * are significant at p= 0.05

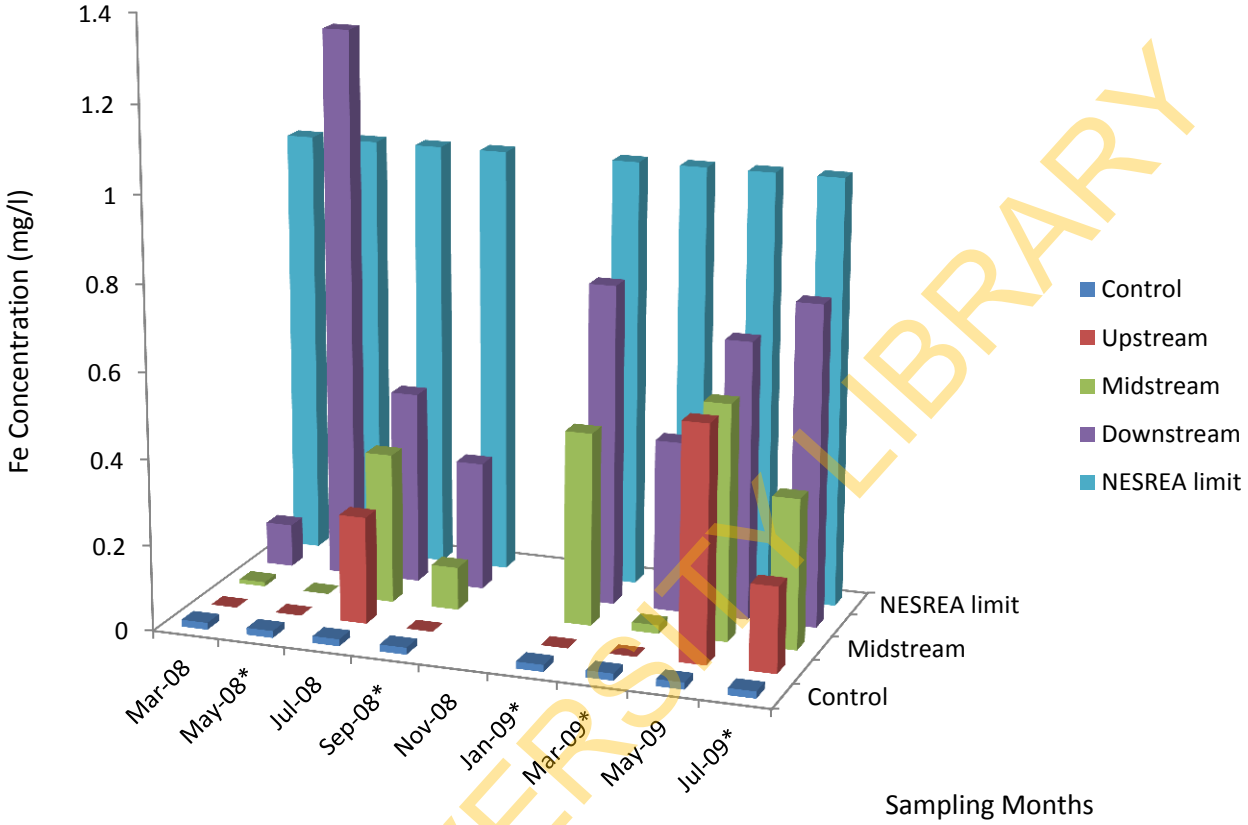


Figure 4.24 Bimonthly Concentration of Iron in Water from Omi Stream

Months with * are significant at p= 0.05

iron concentration ranged from 0.000 mg/l (May 2008) to 0.055 (May 2009) with a mean and standard deviation of 0.263±0.0053 mg/l. The downstream iron concentration ranged from 0.100 mg/l (March 2008) to 1.290 mg/l (May 2008) with a mean and standard deviation of 0.586±0.016 mg/l. The results obtained showed that iron concentration in the control stream was 0.0163 mg/l. The ANOVA results showed that the differences in mean iron concentration in the surface water samples were significant at p=0.05 except March 2008 and May 2008 (Figure 4.24).

Overall, downstream had the highest mean iron concentration (0.586mg/l), which was significantly higher than control (p=0.05) and but less than NESREA standard limit (1.0mg/l) while the upstream had the lowest mean iron concentration (0.125mg/l) and this was significantly lower than control (p=0.05) and NESREA standard limit (0.005mg/l) (Figure 4.24).

4.4 Lead, Cadmium and Iron Concentrations in Maize Samples

The concentrations of lead (Pb), cadmium (Cd) and iron (Fe) measured in the different parts of the cultivated maize namely roots, stems, leaves and grains were compared to values obtained from control and presented in the following sections.

4.4.1 Lead

Lead concentration in the cultivated maize leaf of the West part of the waste dumpsite (direction with the highest heavy metal concentration) ranged from 27.5 mg/l to 49.5 mg/l with a mean and standard deviation of 39.03±0.57 mg/l (Figure 4.25). In the cultivated maize grain, lead concentration ranged from 25.0 mg/l to 49.5 mg/l with a mean and standard deviation of 37.42±1.72 mg/l while that of the cultivated maize stem ranged from 25.5 mg/l to 48.0 mg/l with a mean and standard deviation of 36.42±0.85 mg/l (Figure 4.25). Lead concentration in the cultivated maize root ranged from 29.5 mg/l to 51.5 mg/l with a mean and standard deviation of 40.95±1.98 mg/l (Figure 4.25).

Lead concentration in the control maize leaf ranged from 0.05 mg/l to 0.18 mg/l with a mean and standard deviation of 0.13±0.11 mg/l (Figure 4.25). In the control maize grain, lead concentration was 0.00 mg/l while that of the control maize stem ranged from 0.01 mg/l to 0.11 mg/l with a mean and standard deviation of 0.06±0.02 mg/l

(Figure 4.25). Lead concentration in the control maize root ranged from 0.05 mg/l to 0.14 mg/l with a mean and standard deviation of 0.11±0.04 mg/l (Figure 4.25).

The result obtained showed a significant difference among the mean lead concentration of the different maize parts. The cultivated maize root had the highest lead concentration than the other maize parts. The student's T-test results showed that the differences in mean values for the different maize parts were significant at p=0.05 (Appendix 9).

4.4.2 Cadmium

Cadmium concentration in the cultivated maize leaf of the West part of the waste dumpsite (direction with the highest heavy metal concentration) ranged from 1.25 mg/l to 4.35 mg/l with a mean and standard deviation of 2.65±0.23 mg/l (Figure 4.25). In the cultivated maize grain, cadmium concentration ranged from 1.05 mg/l to 4.15 mg/l with a mean and standard deviation of 2.50±0.35 mg/l while that of the cultivated maize stem ranged from 1.05 mg/l to 4.15 mg/l with a mean and standard deviation of 2.41±0.18 mg/l (Figure 4.25). Cadmium concentration in the cultivated maize root ranged from 1.45 mg/l to 4.55 mg/l with a mean and standard deviation of 2.84±0.19 mg/l (Figure 4.25). Cadmium concentration in the control maize leaf, grain, stem and root was 0.00 mg/l respectively (Figure 4.25).

The result obtained showed a significant difference among the mean cadmium concentration of the different maize parts. The cultivated maize root had the highest cadmium concentration than the other maize parts. The student's T-test results showed that the differences in mean values for the different maize parts were significant at p=0.05 (Appendix 9).

4.4.3 Iron

Iron concentration in the cultivated maize leaf of the West part of the waste dumpsite (direction with the highest heavy metal concentration) ranged from 60.50 mg/l to 105.00 mg/l with a mean and standard deviation of 90.24±20.11 mg/l (Figure 4.25). In the cultivated maize grain, iron concentration ranged from 34.50 mg/l to 92.50 mg/l with a mean and standard deviation of 56.70±12.43 mg/l while that of the cultivated maize stem ranged from 26.00 mg/l to 68.50 mg/l with a mean and standard deviation

of 35.20±13.32 mg/l (Figure 4.25). Iron concentration in the cultivated maize root ranged from 21.50 mg/l to 47.50 mg/l with a mean and standard deviation of 26.70±10.59 mg/l (Figure 4.25).

Iron concentration in the control maize leaf ranged from 56.50 mg/l to 157.00 mg/l with a mean and standard deviation of 103.20±37.61 mg/l (Figure 4.25). In the control maize grain, iron concentration ranged from 50.50 mg/l to 149.50 mg/l with a mean and standard deviation of 83.80±25.13 mg/l while that of the control maize stem ranged from 61.50 mg/l to 178.00 mg/l with a mean and standard deviation of 117.39±40.35 mg/l (Figure 4.25). Iron concentration in the control maize root ranged from 58.50 mg/l to 199.00 mg/l with a mean and standard deviation of 101.89±33.58 mg/l (Figure 4.25).

The result obtained showed a significant difference among the mean iron concentration of the different maize parts. The cultivated maize leaf had the highest iron concentration than the other maize parts. The student's T-test results showed that the differences in mean values for the different maize parts were significant at p=0.05 (Appendix 9).

4.4.4 Transfer Factors and Pollution Load Indices for Lead, Cadmium and Iron in the Cultivated Maize Parts

The transfer factors (TF) and pollution load index (PLI) for each of lead, cadmium and iron in the cultivated maize parts were determined to show the level of uptake and accumulation of the metals in the maize. From the results obtained, the TF and PLI for the maize grains' lead, cadmium and iron were 0.0096 and 0.668; 0.1803 and1.766; as well as 0.0048 and 0.530 respectively while the TF and PLI for the maize stem's lead, cadmium and iron were 0.0094 and 0.663; 0.1755 and 1.760 as well as 0.0046 and 0.523 respectively. The TF and PLI for the maize root's lead, cadmium and iron were 0.0105 and 0.688; 0.1973 and 1.830 as well as 0.0052 and 0.545 respectively while the

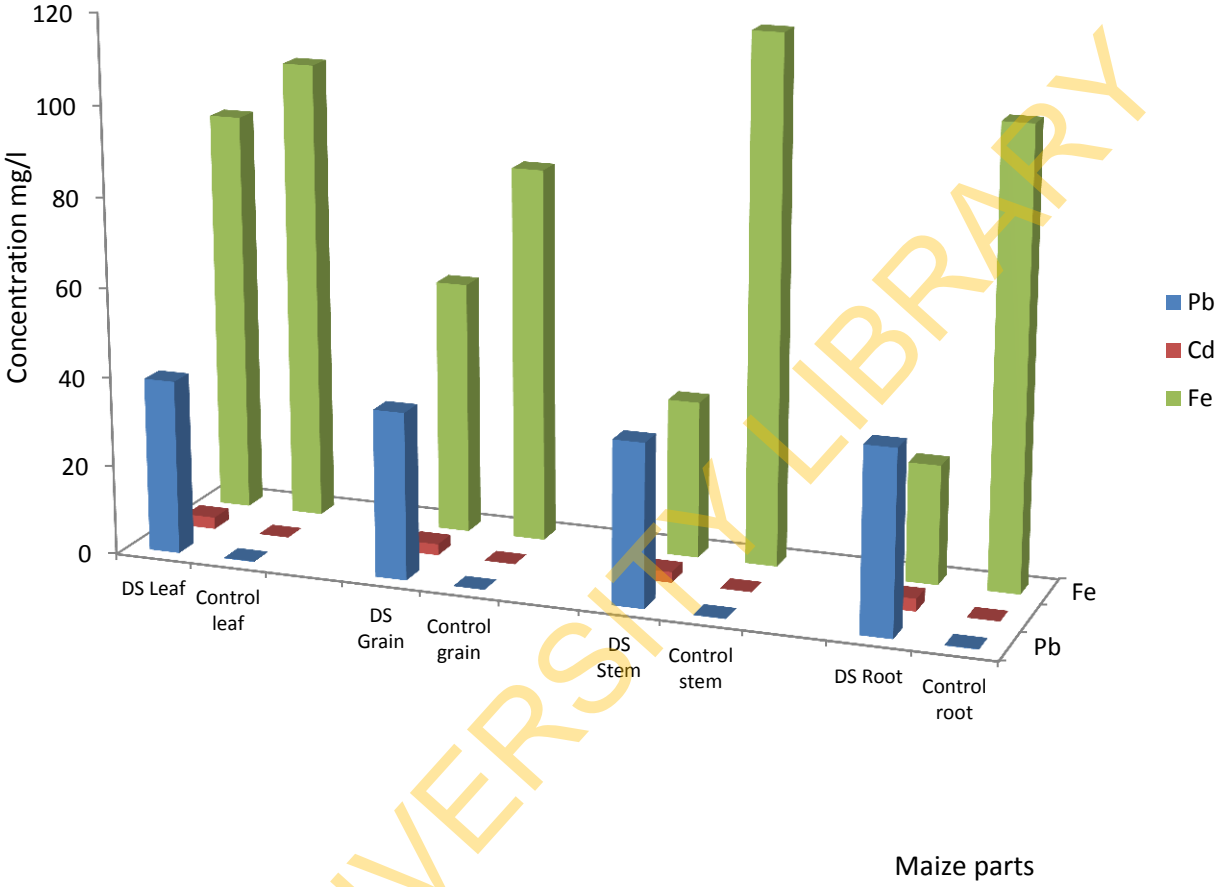


Figure 4.25 Lead, Cadmium and Iron in Cultivated Maize Parts and Control

Key: Each bar represent maize parts; successive colors represents parts' heavy metal concentrations; DS = Dumpsite Area

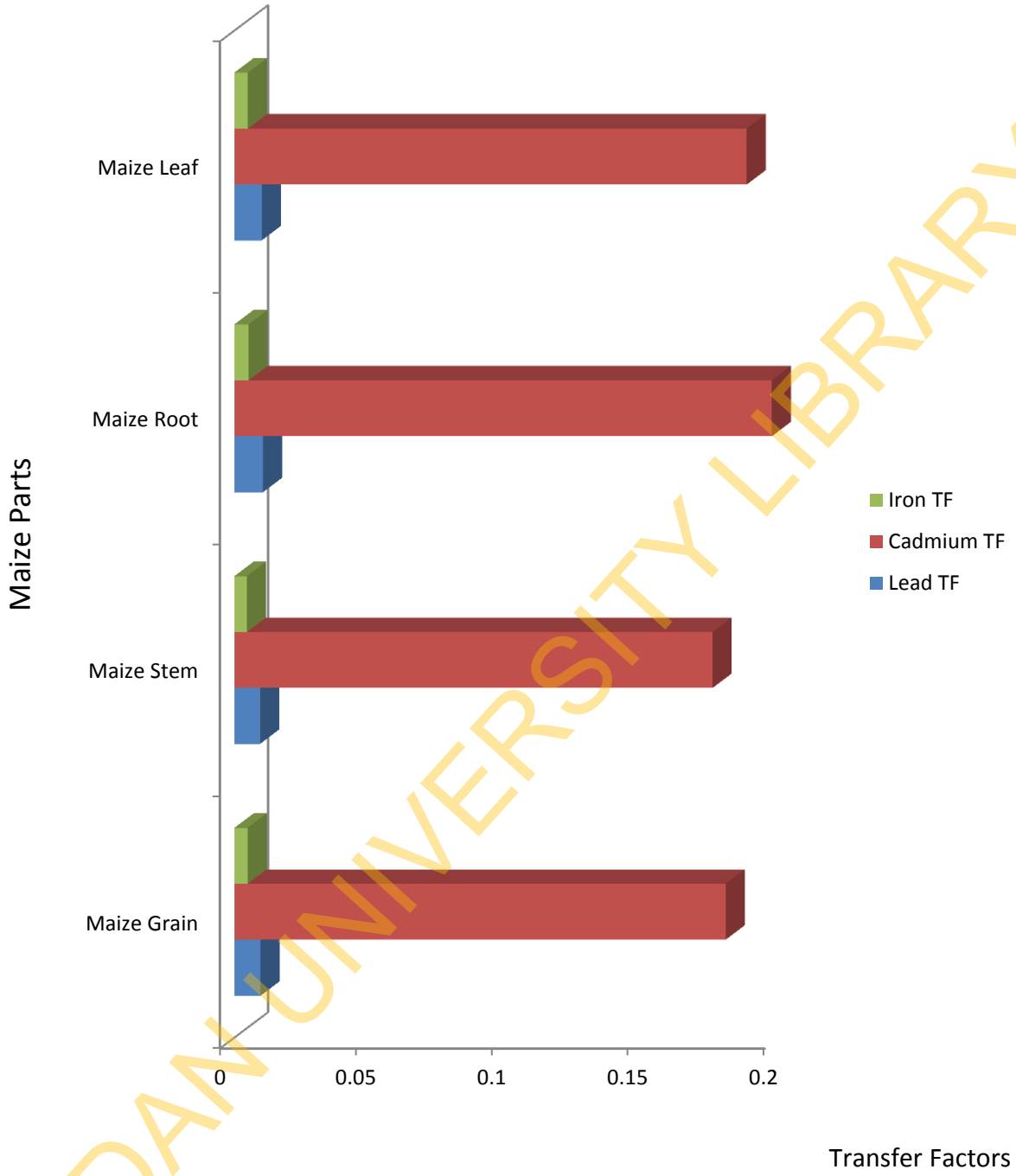


Figure 4.26 Transfer Factors for Lead, Cadmium and Iron in the Cultivated Maize Parts

TF < 1 = low Transfer factor; TF > 1 = high Transfer factor

TF and PLI for the maize leaf's lead, cadmium and iron were 0.0100 and 0.677; 0.1881 and 1.801 as well as 0.0050 and 0.537 respectively. TF in all maize-parts was less than 1 for all the three heavy metals. However, the maize root had the highest TF (TF_{root}> TF_{leaf}> TF_{grain}> TF_{stem}) (Figure 4.26). only the PLI values for cadmium was above one, which indicated that there was higher uptake and accumulation of cadmium in the maize plant from the polluted soil of the waste dumpsite while lead and iron levels were at the baseline.

4.5 Toxicity Assessment of Contaminated Maize Using Broiler Chicks

4.5.1 Growth Parameters of the Broiler Chicks

4.5.1.1 Weight of the Broiler Chicks

The results of the measurement of the weight of the thirty broiler chicks showed that the day-old broilers' weight ranged from 34.00 g to 52.00 g with a mean and standard deviation of 42.97±3.84 g. The weight of the thirty broiler chicks at two weeks old ranged from 67.00 g to 114.00 g with a mean and standard deviation of 94.77±12.10 g (Figure 4.27). At two weeks old, the broiler chicks were divided into two groups of fifteen experimental broilers and fifteen control broilers.

At four weeks old, the weight of the fifteen experimental broiler chicks ranged from 115.00 g to 178.00 g with a mean and standard deviation of 137.87±20.21 g. At six weeks old, the weight of the ten experimental broiler chicks ranged from 217.00 g to 344.00 g with a mean and standard deviation of 273.00±35.51 g. At eight weeks old, the weight of the five experimental broiler chicks ranged from 428.00 g to 588.00 g with a mean and standard deviation of 480.40±62.00 g (Figure 4.27).

At four weeks old, the weight of the fifteen control broiler chicks ranged from 115.00 g to 199.00 g with a mean and standard deviation of 155.33±27.85 g. At six weeks old, the weight of the ten control broiler chicks ranged from 293.00 g to 493.00 g with a mean and standard deviation of 342.60±41.55 g. At eight weeks old, the weight of the five control broiler chicks ranged from 388.00 g to 587.00 g with a mean and standard deviation of 510.20±81.05 g (Figure 4.27).

Overall, student t-test revealed that there was a significant difference between the

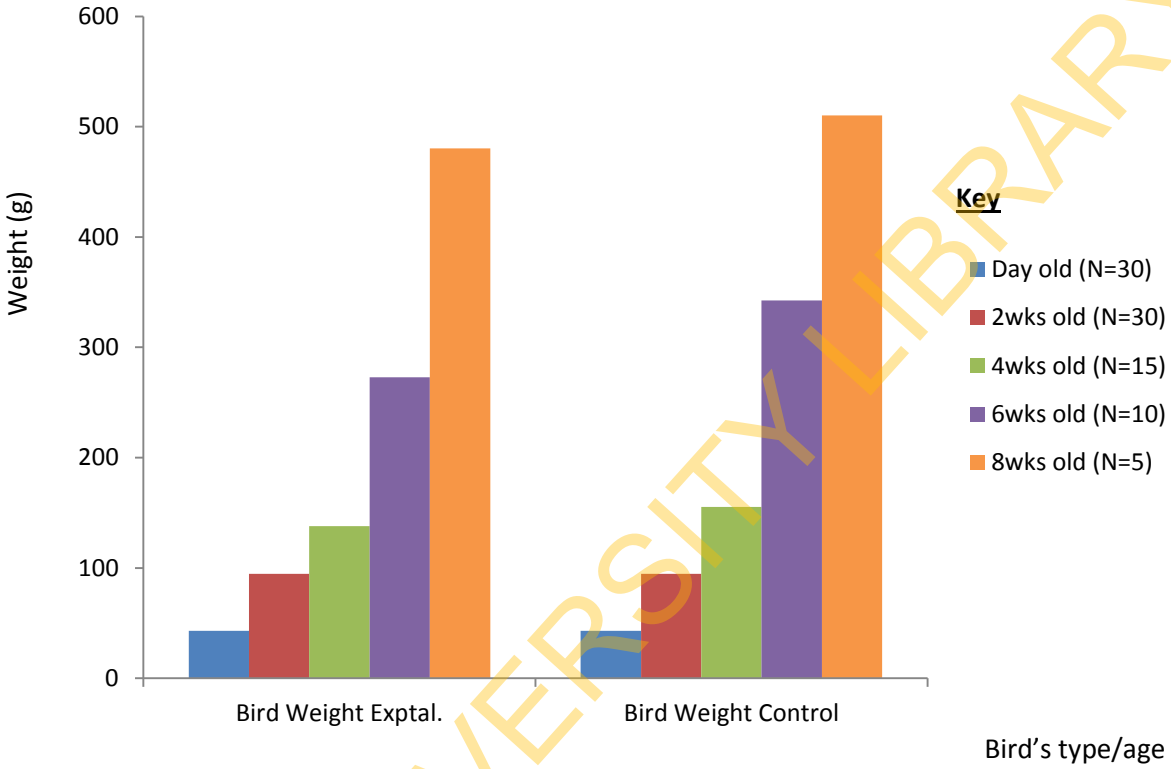


Figure 4.27 Weight of Experimental and Control Broiler at Different Ages

weights of the experimental and control broiler chicks at four, six and eight weeks respectively (Appendix 10).

4.5.1.2 Shank Length of the Broiler Chicks

The results of the measurement of the shank length of the thirty broiler chicks are presented as follows. The shank lengths of the day-old broilers could not be measured due to their being very young and to avoid exposing them to stress. The shank lengths of the broilers at two weeks old ranged from 1.80 cm to 2.10 cm with a mean and standard deviation of 1.95±0.08 cm (Figure 4.28). At two weeks old, the broiler chicks were divided into two groups of fifteen experimental broilers and fifteen control broilers.

At four weeks old, the shank lengths of the fifteen experimental broiler chicks ranged from 2.20 cm to 2.50 cm with a mean and standard deviation of 2.31±0.09 cm. At six weeks old, the shank lengths of the ten experimental broiler chicks ranged from 2.40 cm to 2.60 cm with a mean and standard deviation of 2.51±0.07 cm. At eight weeks old, the shank lengths of the five experimental broiler chicks ranged from 3.00 cm to 3.70 cm with a mean and standard deviation of 3.34±0.25 cm (Figure 4.28).

At four weeks old, the shank length of the fifteen control broiler chicks ranged from 2.20 cm to 2.40 cm with a mean and standard deviation of 2.31±0.08 cm. At six weeks old, the shank length of the ten control broiler chicks ranged from 2.40 cm to 2.60 cm with a mean and standard deviation of 2.50±0.06 cm. At eight weeks old, the shank length of the five control broiler chicks ranged from 3.30 cm to 3.50 cm with a mean and standard deviation of 3.42±0.08 cm (Figure 4.28).'

Overall, student t-test revealed that there was no significant difference between the shank lengths of the experimental and control broiler chicks at four, six and eight weeks respectively (Appendix 10).

4.5.1.3 Wing Length of the Broiler Chicks

The results of the measurement of the wing length of the thirty broiler chicks are presented as follows. The wing lengths of the day-old broilers could also not be measured due to their being very young and to avoid exposing them to stress. The

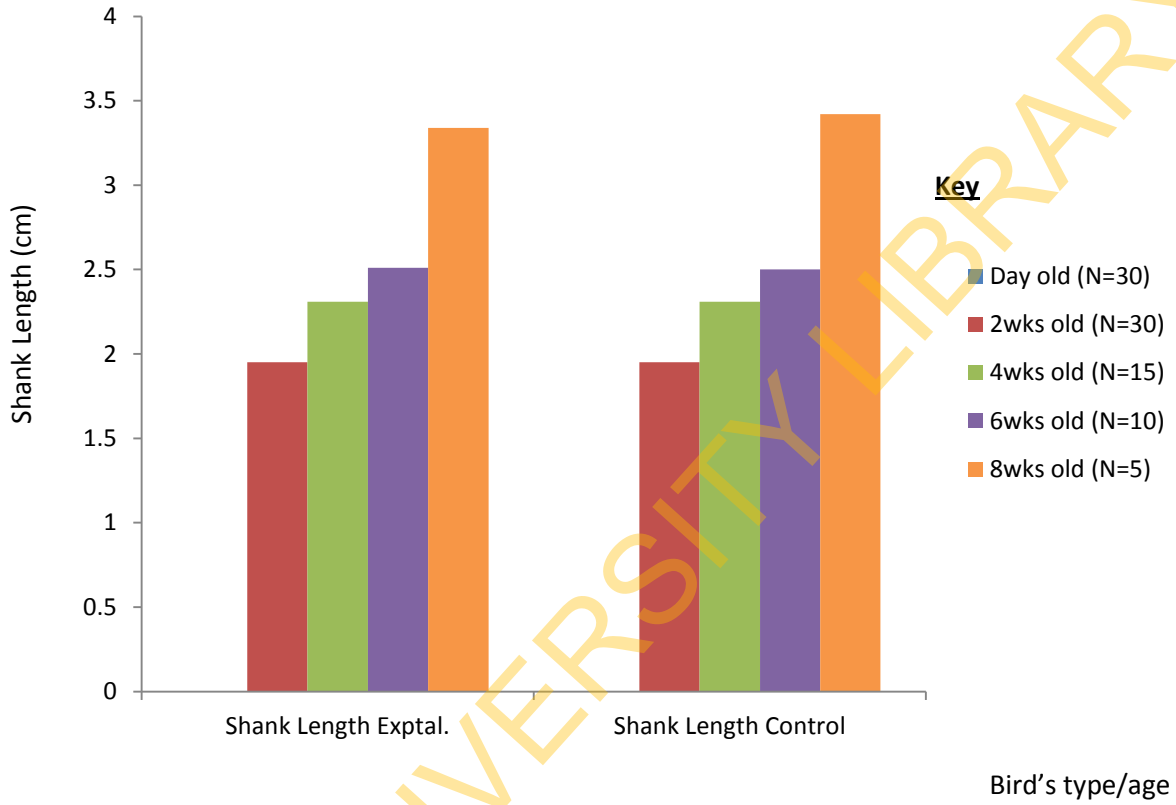


Figure 4.28 Shank Length of Experimental and Control Broiler at Different Ages

wing lengths of the broilers at two weeks old ranged from 9.50 cm to 11.40 cm with a mean and standard deviation of 10.81±0.48 cm (Figure 4.29). At two weeks old, the broiler chicks were divided into two groups of fifteen experimental broilers and fifteen control broilers.

At four weeks old, the wing length of the fifteen experimental broiler chicks ranged from 11.00 cm to 13.70 cm with a mean and standard deviation of 12.16±0.85 cm. At six weeks old, the wing length of the ten experimental broiler chicks ranged from 12.50 cm to 14.20 cm with a mean and standard deviation of 13.44±0.69 cm. At eight weeks old, the wing length of the five experimental broiler chicks ranged from 16.30 cm to 17.80 cm with a mean and standard deviation of 14.74±0.43 cm (Figure 4.29).

At four weeks old, the wing length of the fifteen control broiler chicks ranged from 10.80 cm to 13.80 cm with a mean and standard deviation of 12.39±0.81 cm. At six weeks old, the wing length of the ten control broiler chicks ranged from 12.30 cm to 14.50 cm with a mean and standard deviation of 13.56±0.46 cm. At eight weeks old, the wing length of the five control broiler chicks ranged from 14.80 cm to 16.70 cm with a mean and standard deviation of 15.14±0.40 cm (Figure 4.29).

Overall, student t-test revealed that there was no significant difference between the wing lengths of the experimental and control broiler chicks at four and six weeks old but there was significant difference at eight weeks old (Appendix 10).

4.5.1.4 Girth Size of the Broiler Chicks

The results of the measurement of the girth size of the thirty broiler chicks are presented as follows. The girth sizes of the day-old broilers could also not be measured due to their being very young and to avoid exposing them to stress. The girth sizes of the broilers at two weeks old ranged from 7.20 cm to 8.00 cm with a mean and standard deviation of 7.65±0.32 cm (Figure 4.30). At two weeks old, the broiler chicks were divided into two groups of fifteen experimental broilers and fifteen control broilers. At four weeks old, the girth size of the fifteen experimental broiler chicks ranged from 9.15 cm to 9.83 cm with a mean and standard deviation of 9.34±0.38 cm. At six weeks old, the girth size of the ten experimental broiler chicks ranged from

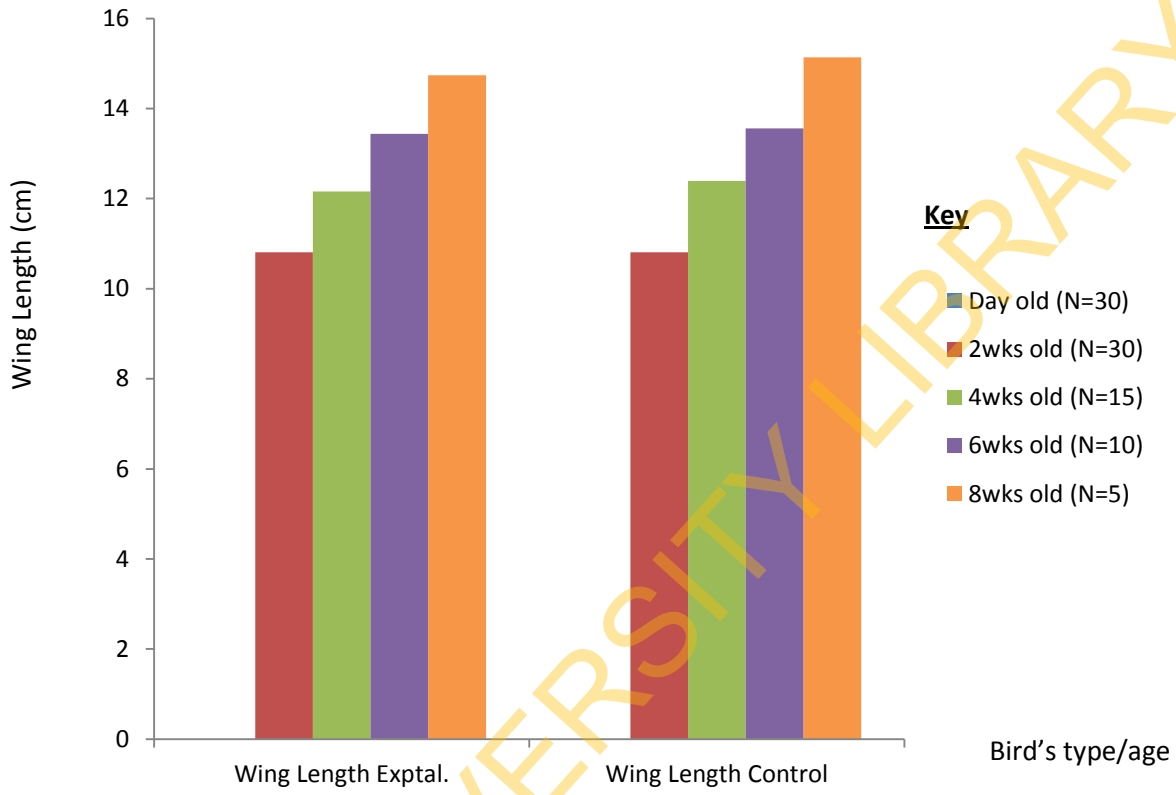


Figure 4.29 Wing Length of Experimental and Control Broiler at Different Ages

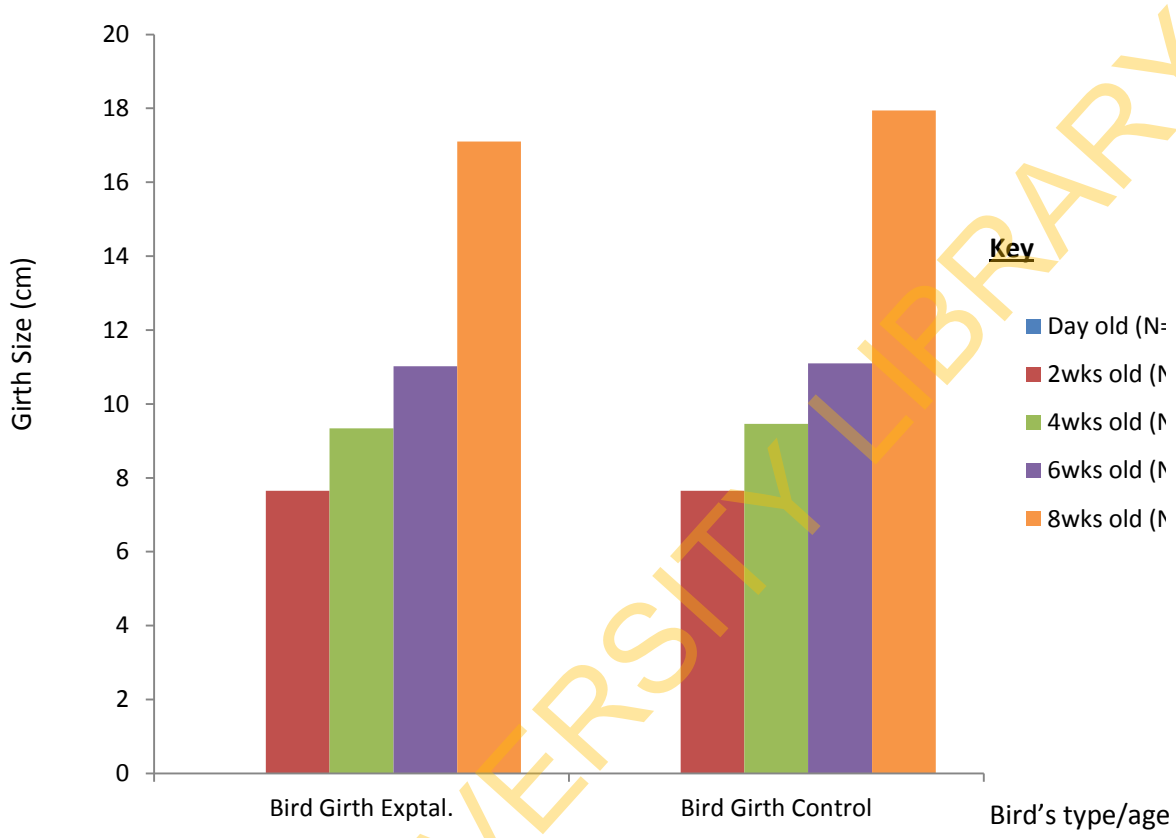


Figure 4.30 Girth Sizes of Experimental and Control Broiler at Different Ages

10.61 cm to 11.25 cm with a mean and standard deviation of 11.02±0.26 cm. At eight weeks old, the girth size of the five experimental broiler chicks ranged from 16.90 cm to 17.35 cm with a mean and standard deviation of 17.10±0.54 cm (Figure 4.30).

At four weeks old, the girth size of the fifteen control broiler chicks ranged from 8.50 cm to 10.00 cm with a mean and standard deviation of 9.46±0.42 cm. At six weeks old, the girth size of the ten control broiler chicks ranged from 10.50 cm to 11.70 cm with a mean and standard deviation of 11.10±0.39 cm. At eight weeks old, the girth size of the five control broiler chicks ranged from 16.20 cm to 19.20 cm with a mean and standard deviation of 17.94±0.99 cm (Figure 4.30).

Overall, student t-test revealed that there was no significant difference between the girth sizes of the experimental and control broiler chicks at four and six weeks old but there was significant difference at eight weeks old (Appendix 10).

4.6 Lead (Pb), Cadmium (Cd) and Iron (Fe) in the Skin, Liver, Femur and Plasma of Experimental Broiler Chicks and Control

The concentrations of each of lead (Pb), cadmium (Cd) and iron (Fe) measured biweekly in the skin, liver, femur and plasma of two to eight weeks old experimental broiler chicks compared with those of the control chicks of the same age are presented as follows:

4.6.1 Lead

In the four (4) weeks old experimental chicks, skin lead concentration ranged from 0.0100 mg/l to 0.0150 mg/l with a mean and standard deviation of 0.0128±0.0023 mg/l while the liver lead concentration ranged from 0.0120 mg/l to 0.0160 mg/l with a mean and standard deviation of 0.0136±0.0017 mg/l. The femur lead concentration ranged from 0.0080 mg/l to 0.0090 mg/l with a mean and standard deviation of 0.0086±0.0005 mg/l while the plasma lead concentration ranged from 0.0060 µg/dl to 0.0090 µg/dl with a mean and standard deviation of 0.072±0.0011 µg/dl (Figure 4.31).

In the four (4) weeks old control chicks, skin lead concentration ranged from 0.0008 mg/l to 0.0010 mg/l with a mean and standard deviation of 0.0009±0.0001 mg/l while

the liver lead concentration ranged from 0.0014 mg/l to 0.0018 mg/l with a mean and standard deviation of 0.0016±0.0001 mg/l. The femur lead concentration ranged from 0.0006 mg/l to 0.0009 mg/l with a mean and standard deviation of 0.0007±0.0001 mg/l while the plasma lead concentration ranged from 0.0003 µg/dl to 0.0007 µg/dl with a mean and standard deviation of 0.0005±0.0001 µg/dl (Figure 4.31). In the six (6) weeks old experimental chicks, skin lead concentration ranged from 0.0080 mg/l to 0.0130 mg/l with a mean and standard deviation of 0.0092±0.0023 mg/l while the liver lead concentration ranged from 0.0040 mg/l to 0.0090 mg/l with a mean and standard deviation of 0.0060±0.0020 mg/l. The femur lead concentration ranged from 0.0080 mg/l to 0.0090 mg/l with a mean and standard deviation of 0.0084±0.0005 mg/l while the plasma lead concentration ranged from 0.0030 µg/dl to 0.0070 µg/dl with a mean and standard deviation of 0.0032±0.0004 µg/dl (Figure 4.31).

In the six (6) weeks old control chicks, skin lead concentration ranged from 0.0005 mg/l to 0.0008 mg/l with a mean and standard deviation of 0.0006±0.0001 mg/l while the liver lead concentration ranged from 0.0003 mg/l to 0.0006 mg/l with a mean and standard deviation of 0.0004±0.0001 mg/l. The femur lead concentration ranged from 0.0005 mg/l to 0.0007 mg/l with a mean and standard deviation of 0.0006±0.0001 mg/l while the plasma lead concentration ranged from 0.0001 µg/dl to 0.0004 µg/dl with a mean and standard deviation of 0.0002±0.0001 µg/dl (Figure 4.31). In the eight (8) weeks old experimental chicks, skin lead concentration ranged from 0.0050 mg/l to 0.0100 mg/l with a mean and standard deviation of 0.0058±0.0015 mg/l while the liver lead concentration ranged from 0.0070 mg/l to 0.0090 mg/l with a mean and standard deviation of 0.0075±0.0009 mg/l. The femur lead concentration ranged from 0.0040 mg/l to 0.0060 mg/l with a mean and standard deviation of 0.0046±0.0005 mg/l while the plasma lead concentration ranged from 0.0030 µg/dl to 0.0060 µg/dl with a mean and standard deviation of 0.0032±0.0016 µg/dl (Figure 4.31).

In the eight (8) weeks old control chicks, skin lead concentration ranged from 0.0004 mg/l to 0.0008 mg/l with a mean and standard deviation of0.0005±0.0001 mg/l while the liver lead concentration ranged from 0.0005 mg/l to 0.0009 mg/l with a mean and

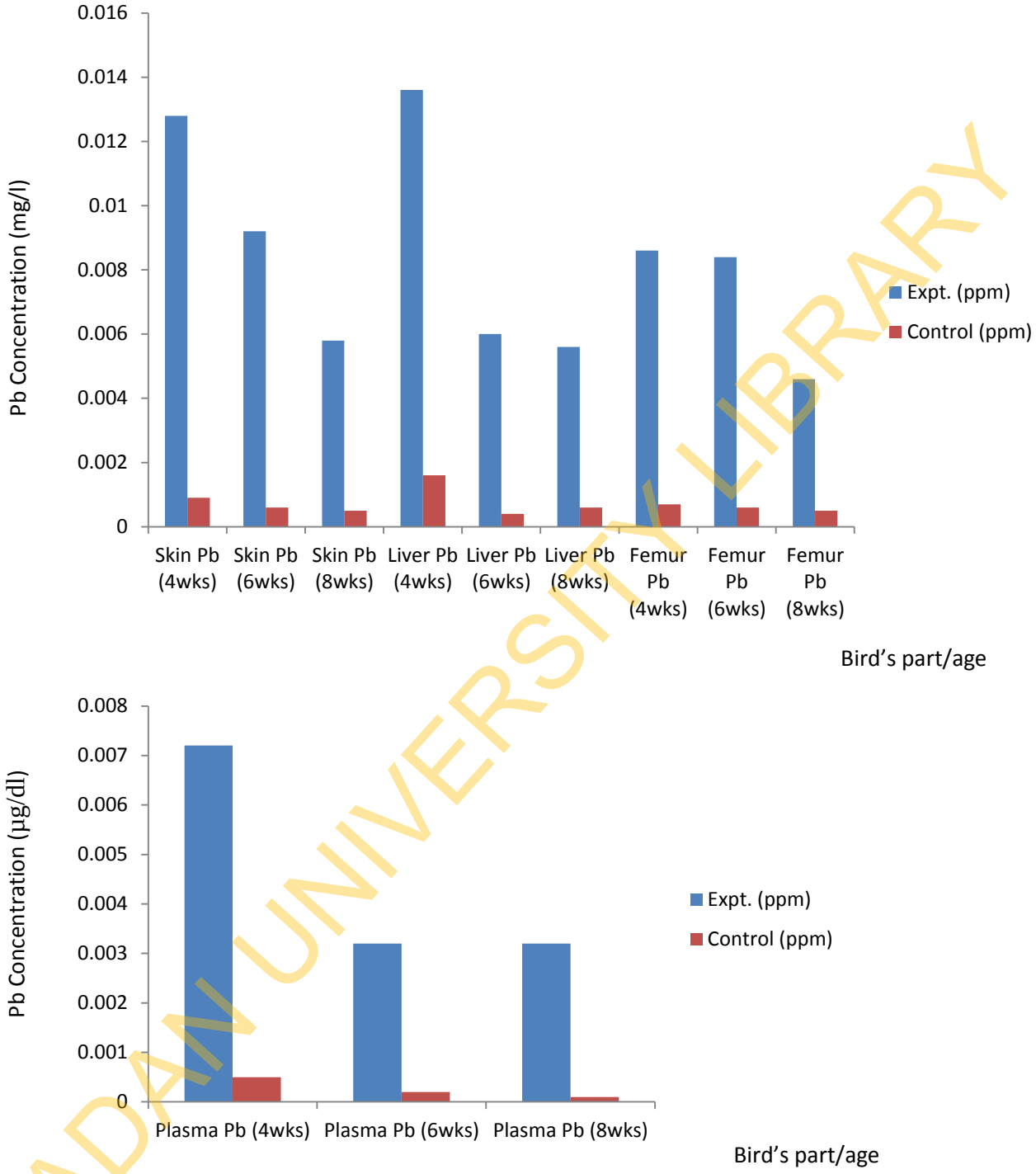


Figure 4.31 Lead Concentration in the Skin, Liver, Femur and Plasma of Experimental Broiler Chicks and Control

standard deviation of0.0006±0.0003 mg/l. The femur lead concentration ranged from 0.0004 mg/l to 0.0006 mg/l with a mean and standard deviation of 0.0005±0.0002 mg/l while the plasma lead concentration ranged from 0.0 µg/dl to 0.0002 µg/dl with a mean and standard deviation of 0.0001±0.0001 µg/dl (Figure 4.31).

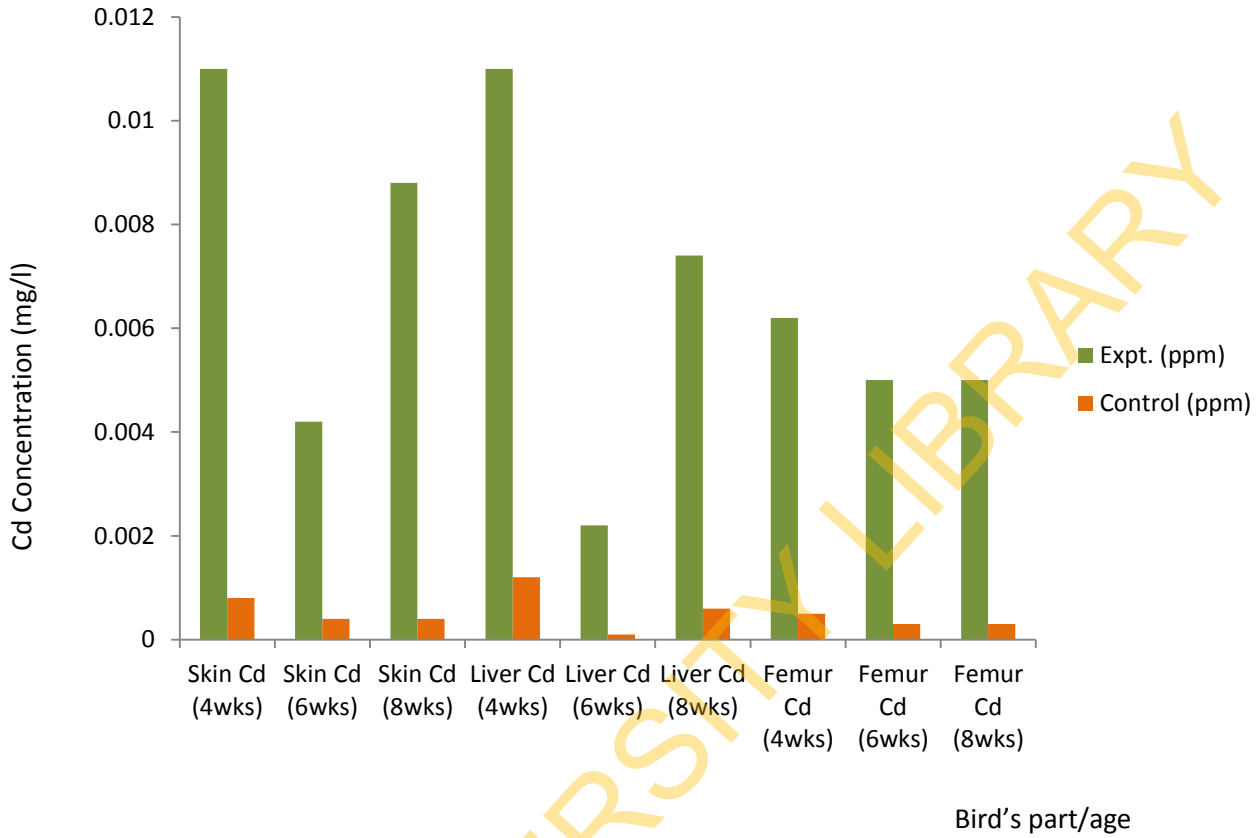
Overall, lead concentrations in all the different analyzed parts of the broiler chicks were significantly higher than those of the control chicks; the liver of four weeks old broiler chicks had the highest mean lead concentration. The student's T-test results showed that the differences in mean values for all the different chick's parts and ages were significant at p=0.05 except for eight (8) weeks old chick's skin, liver and femur (Appendix 11).

4.6.2 Cadmium

In the four (4) weeks old experimental chicks, skin cadmium concentration ranged from 0.0080 mg/l to 0.0140 mg/l with a mean and standard deviation of 0.0110±0.0020 mg/l while the liver cadmium concentration ranged from 0.0070 mg/l to 0.0160 mg/l with a mean and standard deviation of 0.0110±0.0034 mg/l. The femur cadmium concentration ranged from 0.0050 mg/l to 0.0090 mg/l with a mean and standard deviation of 0.0062±0.0016 mg/l while the plasma cadmium concentration ranged from 0.0030 µg/dl to 0.0060 µg/dl with a mean and standard deviation of 0.0036±0.0019 µg/dl (Figure 4.32).

In the four (4) weeks old control chicks, skin cadmium concentration ranged from 0.0006 mg/l to 0.0009 mg/l with a mean and standard deviation of 0.0008±0.0002 mg/l while the liver cadmium concentration ranged from 0.0008 mg/l to 0.0013 mg/l with a mean and standard deviation of 0.0012±0.0003 mg/l. The femur cadmium concentration ranged from 0.0004 mg/l to 0.0006 mg/l with a mean and standard deviation of 0.0005±0.0002 mg/l while the plasma cadmium concentration ranged from 0.0 µg/dl to 0.0003 µg/dl with a mean and standard deviation of 0.0002±0.0001 µg/dl (Figure 4.32).

In the six (6) weeks old experimental chicks, skin cadmium concentration ranged from 0.0040 mg/l to 0.0060 mg/l with a mean and standard deviation of 0.0042±0.0013 mg/l while the liver cadmium concentration ranged from 0.0020 mg/l to 0.0040 mg/l with a



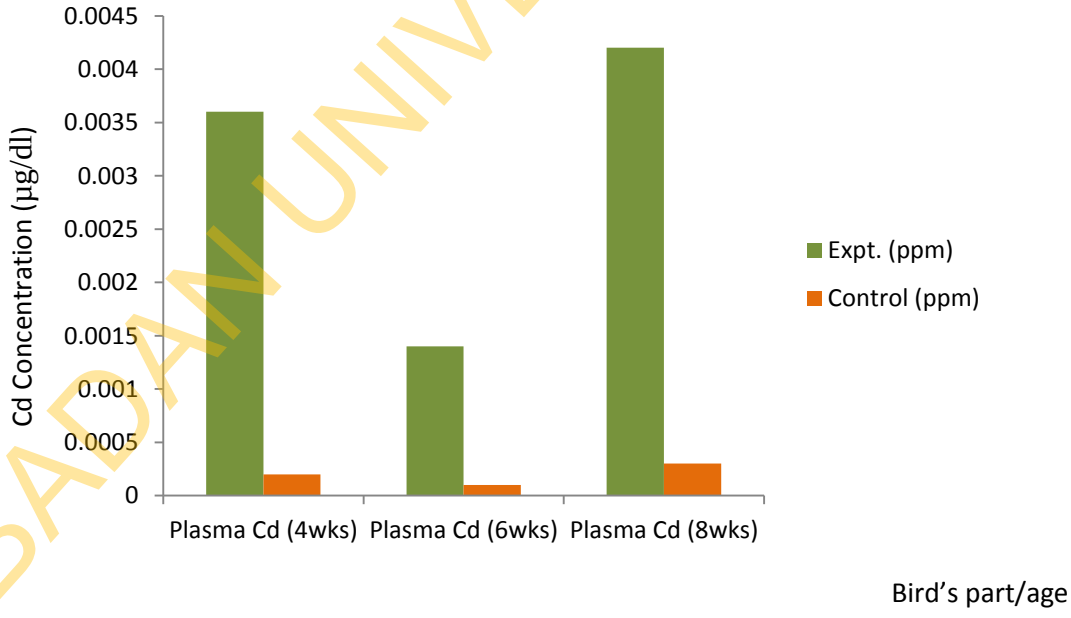


Figure 4.32 Cadmium Concentration in the Skin, Liver, Femur and Plasma of Experimental Broiler Chicks and Control

mean and standard deviation of 0.0022±0.0013 mg/l. The femur cadmium concentration ranged from 0.0050 mg/l to 0.0060 mg/l with a mean and standard deviation of 0.0050±0.0007 mg/l while the plasma cadmium concentration ranged from 0.0 µg/dl to 0.0040 µg/dl with a mean and standard deviation of 0.0014±0.0009 µg/dl (Figure 4.32).

In the six (6) weeks old control chicks, skin cadmium concentration ranged from 0.0003 mg/l to 0.0006 mg/l with a mean and standard deviation of 0.0004±0.0001 mg/l while the liver cadmium concentration ranged from 0.0 mg/l to 0.0002 mg/l with a mean and standard deviation of 0.0001±0.0001 mg/l. The femur cadmium concentration ranged from 0.0003 mg/l to 0.0006 mg/l with a mean and standard deviation of 0.0003±0.0000 mg/l while the plasma cadmium concentration ranged from 0.0 µg/dl to 0.0002 µg/dl with a mean and standard deviation of 0.0001±0.0000 µg/dl (Figure 4.32).

In the eight (8) weeks old experimental chicks, skin cadmium concentration ranged from 0.0070 mg/l to 0.0090 mg/l with a mean and standard deviation of 0.0088±0.0022 mg/l while the liver cadmium concentration ranged from 0.0050 mg/l to 0.0100 mg/l with a mean and standard deviation of 0.0074±0.0005 mg/l. The femur cadmium concentration ranged from 0.0030 mg/l to 0.0070 mg/l with a mean and standard deviation of 0.0050±0.0007 mg/l while the plasma cadmium concentration ranged from 0.0030 µg/dl to 0.0060 µg/dl with a mean and standard deviation of 0.0042±0.0008 µg/dl (Figure 4.32).

In the eight (8) weeks old control chicks, skin cadmium concentration ranged from 0.0003 mg/l to 0.0005 mg/l with a mean and standard deviation of 0.0004±0.0001 mg/l while the liver cadmium concentration ranged from 0.0005 mg/l to 0.0009 mg/l with a mean and standard deviation of0.0006±0.0001 mg/l. The femur cadmium concentration ranged from 0.0002 mg/l to 0.0005 mg/l with a mean and standard deviation of 0.0003±0.0001 mg/l while the plasma cadmium concentration ranged from 0.0001 µg/dl to 0.0004 µg/dl with a mean and standard deviation of 0.0003±0.0000 µg/dl (Figure 4.32).

Overall, the cadmium concentrations in all the different analyzed parts of the broiler chicks were significantly higher than those of the control chicks and the highest mean

cadmium concentration was also found in the liver and skin of four weeks old broiler chicks. The student's T-test results showed that the differences in mean values for all the different chick's parts and ages were not significant at p=0.05 except for six (6) weeks old chick's femur as well as eight (8) weeks old chick's skin, liver, femur and plasma (Appendix 11).

4.6.3 Iron

In the four (4) weeks old experimental chicks, skin iron concentration ranged from 128.29 mg/l to 152.18 mg/l with a mean and standard deviation of 145.4026±12.9433 mg/l while the liver iron concentration ranged from 264.31 mg/l to 309.15 mg/l with a mean and standard deviation of 302.0070±28.0225 mg/l. The femur iron concentration ranged from 108.92 mg/l to 129.37 mg/l with a mean and standard deviation of 122.5098±11.2748 mg/l while the plasma iron concentration ranged from 116.20 µg/dl to 142.00 µg/dl with a mean and standard deviation of 137.5656±13.7419 µg/dl (Figure 4.33).

In the four (4) weeks old control chicks, skin iron concentration ranged from 148.32 mg/l to 162.02 mg/l with a mean and standard deviation of 152.4848±6.7872 mg/l while the liver iron concentration ranged from 270.25 mg/l to 346.73 mg/l with a mean and standard deviation of 304.7774±30.7782 mg/l. The femur iron concentration ranged from 109.68 mg/l to 141.11 mg/l with a mean and standard deviation of 128.4566±11.8363 mg/l while the plasma iron concentration ranged from 134.22 µg/dl to 153.29 µg/dl with a mean and standard deviation of 140.9444±8.9344 µg/dl (Figure 4.33).

In the six (6) weeks old experimental chicks, skin iron concentration ranged from 120.51 mg/l to 137.00 mg/l with a mean and standard deviation of 133.6300±8.4735 mg/l while the liver iron concentration ranged from 259.13 mg/l to 295.95 mg/l with a mean and standard deviation of 281.4954±15.5327 mg/l. The femur iron concentration ranged from 90.51 mg/l to 106.00 mg/l with a mean and standard deviation of 101.0642±7.1725 mg/l while the plasma iron concentration ranged from 120.12 µg/dl to 141.14 µg/dl with a mean and standard deviation of 133.5894±5.4447 µg/dl (Figure 4.33).

In the six (6) weeks old control chicks, skin iron concentration ranged from 139.54 mg/l to 281.68 mg/l with a mean and standard deviation of 167.0890±6.4381 mg/l while the liver iron concentration ranged from 296.85 mg/l to 301.00 mg/l with a mean and standard deviation of 291.7246±16.4760 mg/l. The femur iron concentration ranged from 103.61 mg/l to 161.11 mg/l with a mean and standard deviation of 122.6196±23.7921 mg/l while the plasma iron concentration ranged from 129.20 µg/dl to 188.64 µg/dl with a mean and standard deviation of 135.4772±14.1722 µg/dl (Figure 4.33).

In the eight (8) weeks old experimental chicks, skin iron concentration ranged from 79.00 mg/l to 91.21 mg/l with a mean and standard deviation of 86.1292±6.0912 mg/l while the liver iron concentration ranged from 260.02 mg/l to 301.16 mg/l with a mean and standard deviation of 300.7590±23.0803 mg/l. The femur iron concentration ranged from 141.80 mg/l to 159.91 mg/l with a mean and standard deviation of 155.4140±16.1975 mg/l while the plasma iron concentration ranged from 169.20 µg/dl to 183.37 µg/dl with a mean and standard deviation of 175.7858±5.2186 µg/dl (Figure 4.33).

In the eight (8) weeks old control chicks, skin iron concentration ranged from 87.01 mg/l to 99.61 mg/l with a mean and standard deviation of 88.1230±3.7054 mg/l while the liver iron concentration ranged from 286.05 mg/l to 312.12 mg/l with a mean and standard deviation of 301.5208±11.2425 mg/l. The femur iron concentration ranged from 129.71 mg/l to 181.00 mg/l with a mean and standard deviation of 155.9890±11.7320 mg/l while the plasma iron concentration ranged from 171.56 µg/dl to 186.59 µg/dl with a mean and standard deviation of 177.9554±5.8996 µg/dl (Figure 4.33).

Overall, the iron concentrations in all the different analyzed parts of the broiler chicks was significantly less than those of the control chicks and the highest mean iron concentration was found in the liver of four weeks old broiler chicks. The student's T-test results showed that the differences in mean values for all the different chick's parts and ages were not significant at p=0.05 (Appendix 11).

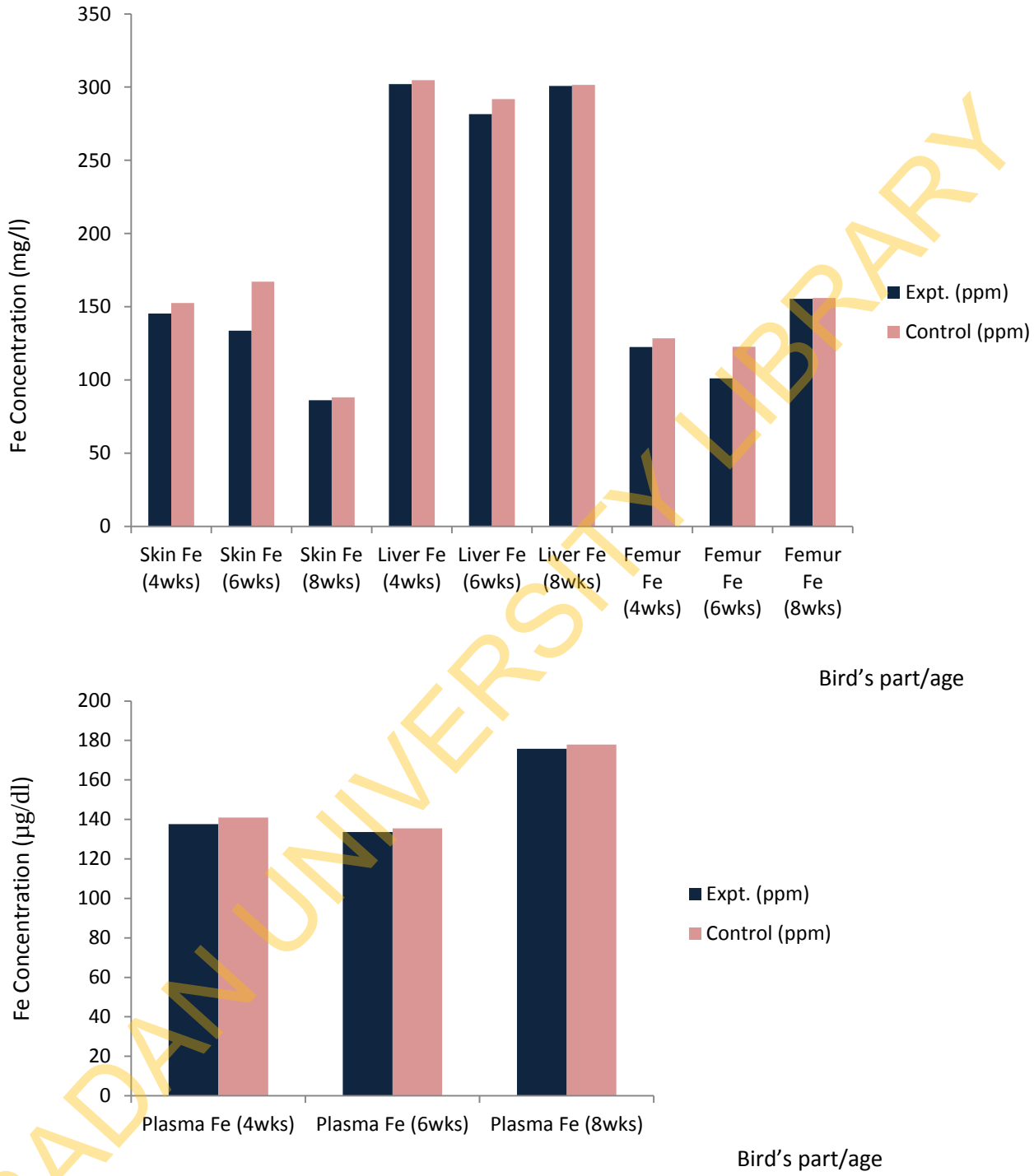


Figure 4.33 Iron Concentration in the Skin, Liver, Femur and Plasma of Experimental Broiler Chicks and Control

4.6.4 Bio-accumulation Factors and Pollution Load Indices for Lead, Cadmium and Iron in the Skin, Liver, Femur and Plasma of Broiler Chicks

The calculated bio-accumulation factors (B_aF) and pollution load index (PLI) for each of lead, cadmium and iron in the skin, liver, femur and plasma of the broiler chicks revealed the extent of accumulation of the metals in the broiler chicks.

From the results obtained, the skin's calculated BaF and PLI for lead were 0.0015 and 0.36; cadmium was 0.00030 and 0.210 while iron was 2.4570 and 4.241 (Figure 4.34). The liver's calculated BaF and PLI for lead were 0.0018 and 0.382; cadmium was 0.00024 and 0.195; iron was 7.9640 and 6.277 while that of the femur were 0.0013 and 0.343 for lead; cadmium: 0.00022 and 0.190; iron: 3.9340 and 4.962 (Figure 4.34). The plasma's calculated BaF and PLI for lead were 0.0011 and 0.324; cadmium were 0.00016 and 0.171; iron were 4.7430 and 5.281(Figure 4.34).

Overall, lead and cadmium BaF and PLIs for all the broiler chicks were less than 1though iron BaF and PLIs in all the broiler chicks were greater than 1(Fe>1). Lead and cadmium BaF and PLIs indicate low level of absorption and accumulation in the tissue of the broiler while iron BaF and PLIs indicate high level of absorption and accumulation of iron in the tissue of the broiler chicks (Figure 4.34).

4.7 Lead, Cadmium and Iron in the Skin, Liver, Femur and Plasma of Free-Range Local Chicks of Ori-Ile Olodo Community and Control

The concentrations of each of lead , cadmium and iron measured in the skin, liver, femur and plasma of eight weeks old free-range local chicks of Ori-Ile Olodo community compared with those of the control chicks of the same age are presented as follows:

4.7.1 Lead

Lead concentrations in the eight weeks old free-range local chicks of Ori-Ile Olodo community were significantly higher than those in the control chicks. In the eight weeks old free-range local chicks of Ori-Ile Olodo community, skin lead concentration ranged from 0.0300 mg/l to 0.0800 mg/l with a mean and standard deviation of

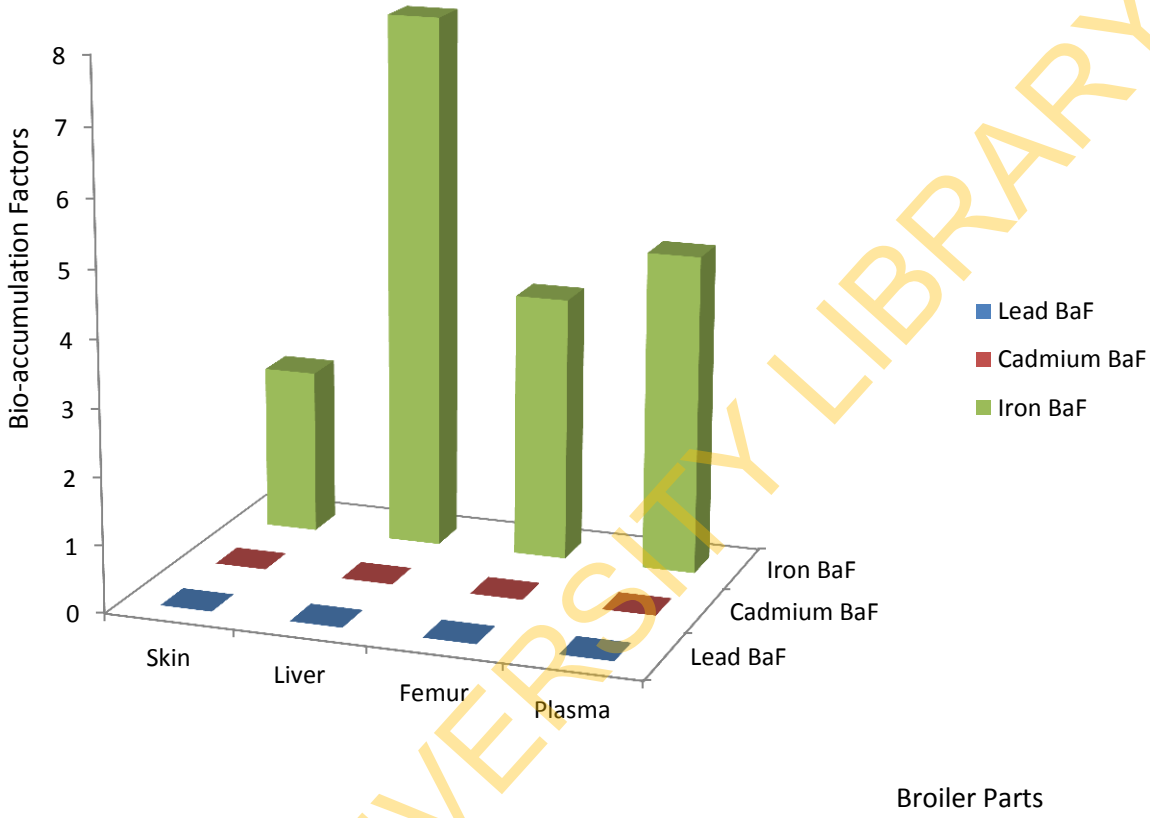


Figure 4.34 Bio-accumulation Factors for Lead, Cadmium and Iron in the Skin, Liver, Femur and Plasma of Broiler Chicks

BaF < 1 = low bio-accumulation factor; BaF > 1 = high bio-accumulation factor

0.0580±0.010 mg/l while the liver lead concentration ranged from 0.0500 mg/l to 0.0900 mg/l with a mean and standard deviation of 0.0680±0.0150 mg/l. The femur lead concentration ranged from 0.0400 mg/l to 0.1000 mg/l with a mean and standard deviation of 0.0500±0.0000 mg/l while the plasma lead concentration ranged from 0.0200 µg/dl to 0.0800 µg/dl with a mean and standard deviation of 0.0400±0.0140 µg/dl (Figure 4.35).

In the eight (8) weeks old control chicks, skin lead concentration ranged from 0.0040 mg/l to 0.0070 mg/l with a mean and standard deviation of 0.0055±0.0007 mg/l while the liver lead concentration ranged from 0.0050 mg/l to 0.0090 mg/l with a mean and standard deviation of 0.0065±0.0007 mg/l. The femur lead concentration ranged from 0.0040 mg/l to 0.0060 mg/l with a mean and standard deviation of 0.0048±0.0005 mg/l while the plasma lead concentration ranged from 0.0020 µg/dl to 0.0050 µg/dl with a mean and standard deviation of 0.0035±0.0013 µg/dl (Figure 4.35).

Overall, the liver of the free-range local Ori-Ile Olodo chicks have the highest mean lead concentration. The student's T-test results showed that the differences in mean values for all the different chick's parts were not significant at p=0.05 (Appendix 12).

4.7.2 Cadmium

Cadmium concentrations in the eight weeks old free-range local chicks of Ori-Ile Olodo community were significantly higher than those in the control chicks. In the eight weeks old free-range local chicks of Ori-Ile Olodo community, skin cadmium concentration ranged from 0.0090 mg/l to 0.01600 mg/l with a mean and standard deviation of 0.0125±0.0024 mg/l while the liver cadmium concentration ranged from 0.0060 mg/l to 0.0110 mg/l with a mean and standard deviation of 0.0088±0.0005 mg/l. The femur cadmium concentration ranged from 0.0060 mg/l to 0.0100 mg/l with a mean and standard deviation of 0.0083±0.0010 mg/l while the plasma cadmium concentration ranged from 0.0040 µg/dl to 0.0080 µg/dl with a mean and standard deviation of 0.0055±0.0006 µg/dl (Figure 4.36).

In the eight (8) weeks old control chicks, skin cadmium concentration ranged from 0.0020 mg/l to 0.0050 mg/l with a mean and standard deviation of 0.0025±0.0007 mg/l while the liver cadmium concentration ranged from 0.0040 mg/l to 0.0080 mg/l with a

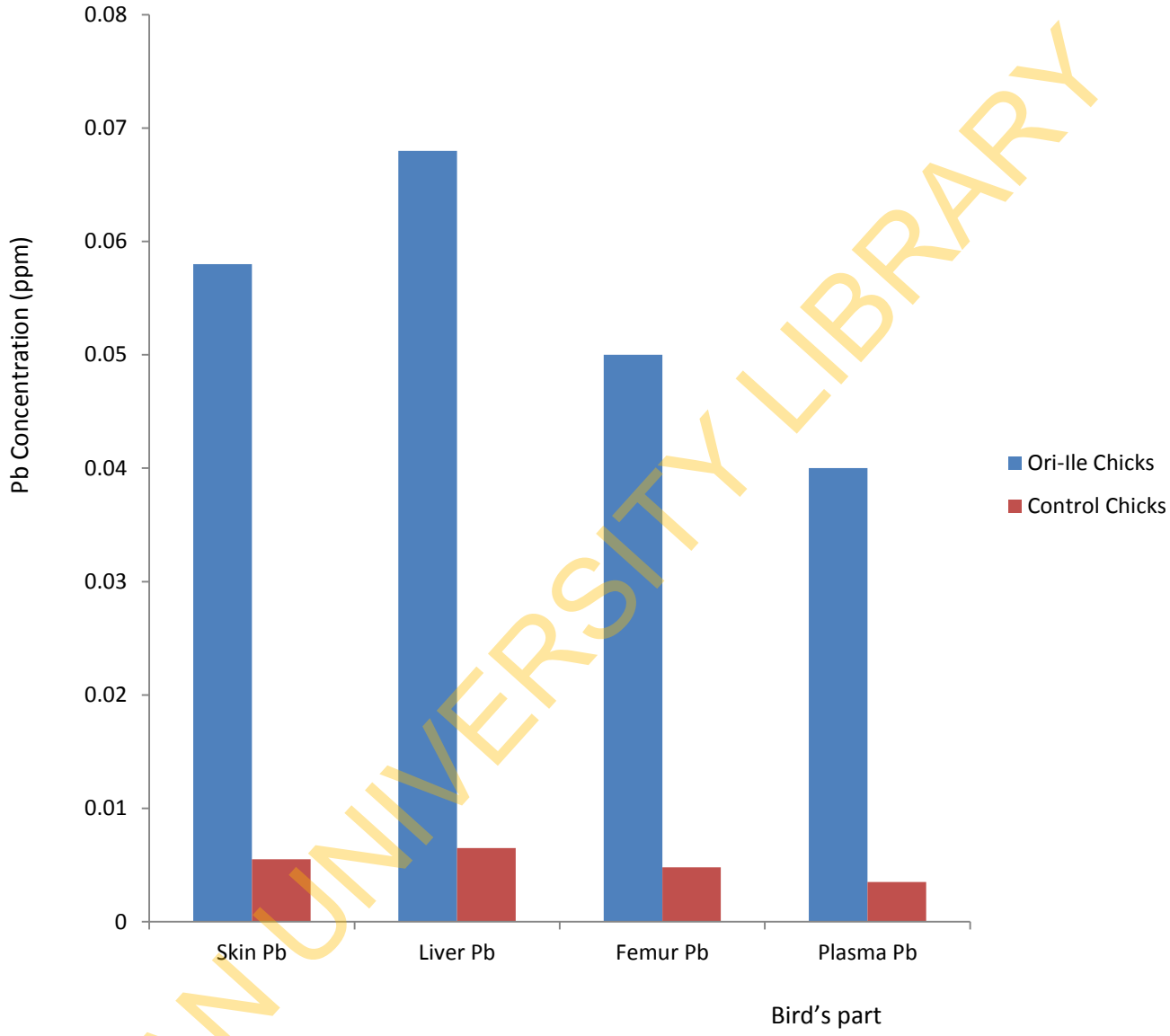


Figure 4.35 Lead Concentration in Skin, Liver, Femur and Plasma of Free-Range Local Ori-Ile Olodo Chicks and Control

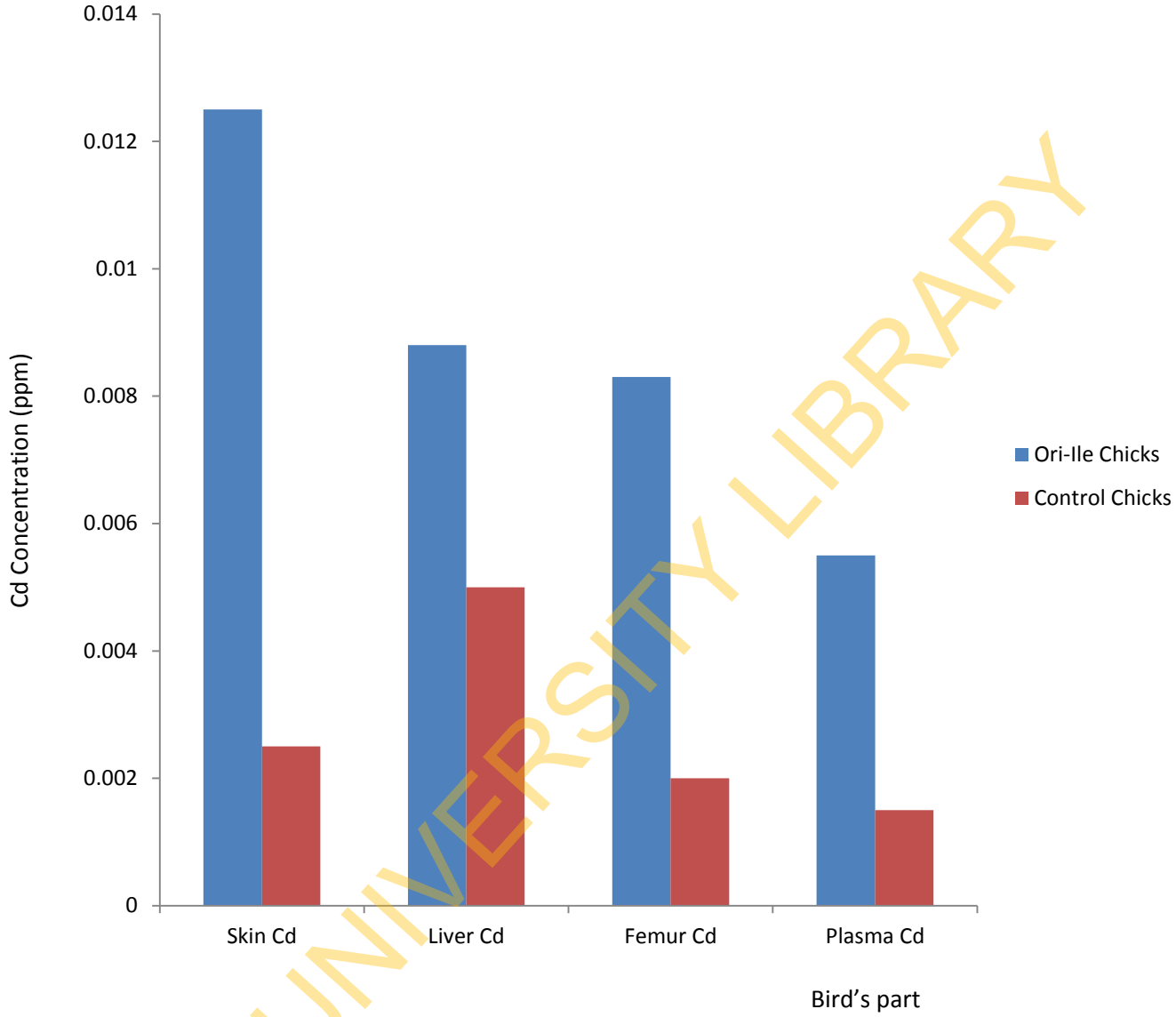


Figure 4.36 Cadmium Concentration in Skin, Liver, Femur and Plasma of Free-Range Local Ori-Ile Olodo Chicks and Control

mean and standard deviation of 0.0050±0.0000 mg/l. The femur cadmium concentration ranged from 0.0010 mg/l to 0.0030 mg/l with a mean and standard deviation of 0.0020±0.0000 mg/l while the plasma cadmium concentration ranged from 0.00 µg/dl to 0.0020 µg/dl with a mean and standard deviation of 0.0015±0.0007 µg/dl (Figure 4.36).

Overall, the skin of the free-range local Ori-Ile Olodo chicks has the highest mean cadmium concentration. The student's T-test results showed that the differences in mean values for all the different chick's parts were not significant at p=0.05 (Appendix 13).

4.7.3 Iron

Iron concentrations in the eight weeks old free-range local chicks of Ori-Ile Olodo community were significantly less than those in the control chicks. In the eight weeks old free-range local chicks of Ori-Ile Olodo community, skin iron concentration ranged from 89.75 mg/l to 121.77 mg/l with a mean and standard deviation of 91.94±0.93 mg/l while the liver iron concentration ranged from 291.26 mg/l to 312.12 mg/l with a mean and standard deviation of 298.00±8.48 mg/l. The femur iron concentration ranged from 142.26 mg/l to 151.79 mg/l with a mean and standard deviation of 147.21±7.07 mg/l while the plasma iron concentration ranged from 165.99 µg/dl to 189.61 µg/dl with a mean and standard deviation of 177.47±8.35 µg/dl (Figure 4.37).

In the eight (8) weeks old control chicks, skin iron concentration ranged from 91.71 mg/l to 95.01 mg/l with a mean and standard deviation of 93.66±8.42 mg/l while the liver iron concentration ranged from 306.76 mg/l to 315.20 mg/l with a mean and standard deviation of 311.11±5.79 mg/l. The femur iron concentration ranged from 160.22 mg/l to 163.19 mg/l with a mean and standard deviation of 161.3065±2.7179 mg/l while the plasma iron concentration ranged from 175.64 µg/dl to 181.22 µg/dl with a mean and standard deviation of 178.2538±9.6679 µg/dl (Figure 4.37).

Overall, the liver of the free-range local Ori-Ile Olodo chicks have the highest mean iron concentration. The student's T-test results showed that the differences in mean values for all the different chick's parts were not significant at p=0.05 (Appendix 14).

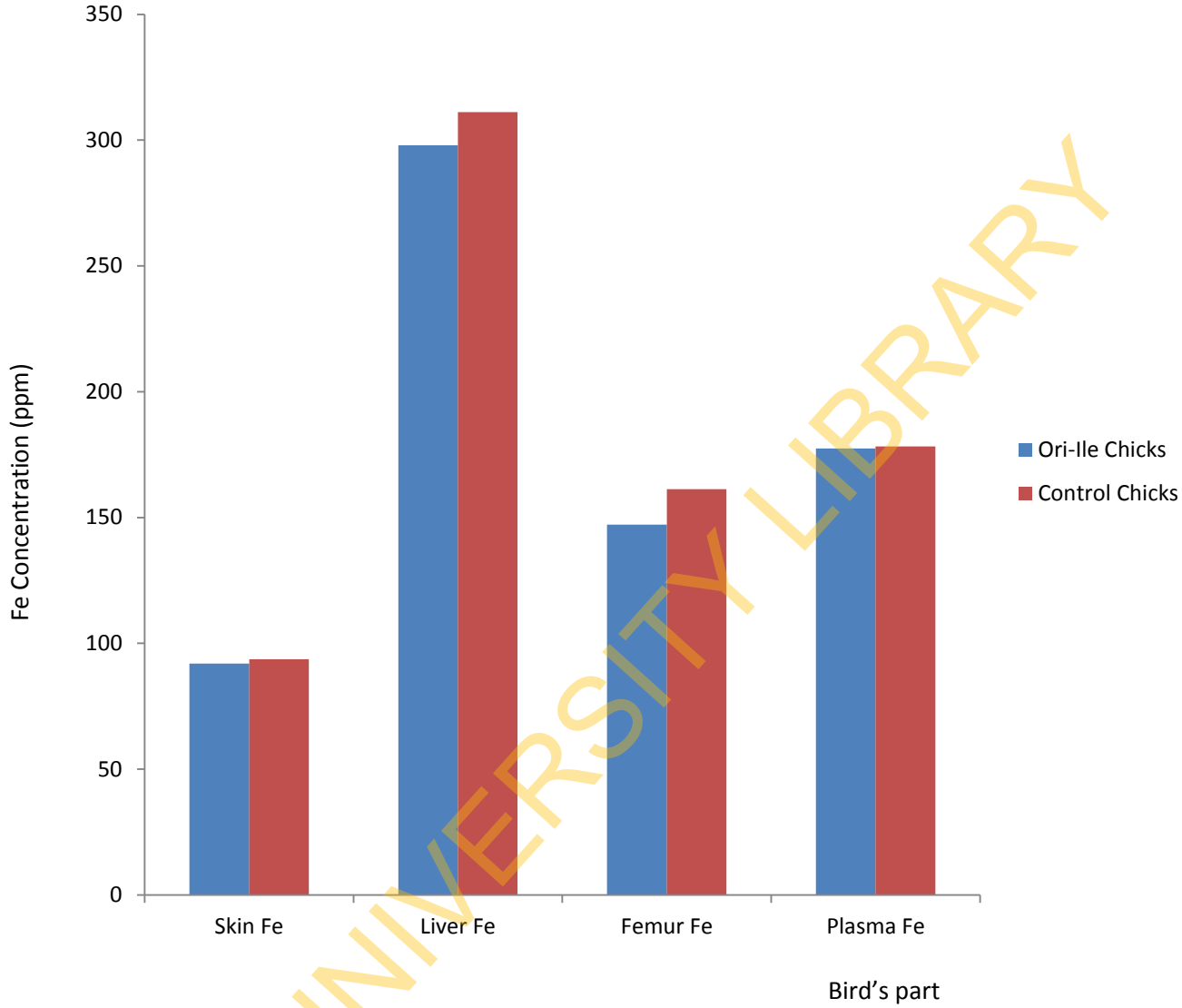


Figure 4.37 Iron Concentration in Skin, Liver, Femur and Plasma of Free-Range Local Ori-Ile Olodo Chicks and Control

4.7.4 Correlation Coefficient Matrices of the Heavy Metals

4.7.4.1 Correlation Coefficient Matrices of the Metals in Broiler Chicks

Lead content in the four weeks old broiler chicks correlated positively with iron and cadmium contents of all the different ages of broilers assessed but had negative correlation with lead contents of eight weeks old broilers and no correlation with the lead content of the six weeks old chicks only. Also, lead content in the six weeks old broiler chicks correlated significantly with iron, lead and cadmium contents of all the different ages of broilers assessed but had negative correlation with cadmium contents of four weeks old broilers. Lead content in the eight weeks old broiler chicks correlated negatively with iron, lead and cadmium contents of four weeks old broiler, while it had positive correlation with lead contents of six weeks old chicks but no correlation with the rest categories. Iron content in the four weeks old broiler chicks correllated positively and significantly with iron, lead and cadmium contents of all the different ages of broilers assessed but had negative correllation with lead contents of eight weeks old broilers and no correllation with the lead content of the six weeks old chicks.

Similarly, the iron content in the six and eight weeks old broiler chicks correllated significantly with iron, lead and cadmium contents of all the different ages of broilers assessed except with the lead content of the eight weeks old chicks and the cadmium content of four weeks old. Cadmium content in the four weeks old broiler chicks correllated negatively with lead content of six weeks old broiler, while it had positive correlation with iron and lead contents of four weeks old chicks and no correllation with the rest categories. Cadmium contents in the six and eight weeks old broiler chicks correllated positively with iron, lead and cadmium contents of all the different ages of broilers assessed except with cadmium of four weeks old broilers.

4.7.4.2 Correlation Coefficient Matrices of the Metals in Free-Range Local Chicks of Ori-Ile Olodo Community

For the local chicks' organs assessed, the result showed that iron concentration correlated positively with lead concentration. Similarly, cadmium concentration in the chicks' organs had a positive correllation with lead concentration. However, the result further indicated that there was no correlation whatsoever between iron and cadmium concentration within the local chicks parts.

4.8 Haematological Values of the Blood of Broilers and Free-Range Local Chicks

The results of the haematological parameters of the blood of broilers and free-ranged local Ori-Ile Olodo chicks compared to their respective controls are presented as follows.

4.8.1 Haematological Values of the Blood of Experimental Broilers

The results of the haematological parameters of the four-, six-, and eight-week old experimental broilers fed with feed formulated from Ori-Ile Olodo cultivated maize were compared with the control broilers raised with the feed formulated from control maize and are shown in Tables 2 to 5.

The Packed Cell Volume (PCV) of four weeks old experimental broiler ranged from 16.00 % to 21.00 % with a mean and standard deviation of 19.60±2.07 % while that of control broilers ranged from 19.00 % to 27.00 % with a mean and standard deviation of 21.8±3.27 %. The Red Blood Cells (RBC) count of four weeks old experimental broiler ranged from 3.02 $x10^{12}$/l to 4.88 $x10^{12}$/l with a mean and standard deviation of 3.58±0.76 $x10^{12}$/l while that of control broilers ranged from 3.84 $x10^{12}$/l to 4.92 $x10^{12}$/l with a mean and standard deviation of 4.24±0.41 $x10^{12}$/l. The White Blood Cells (WBC) Count of four weeks old experimental broiler ranged from 10.40 $x10^{9}$/l to 20.00 $x10^{9}$/l with a mean and standard deviation of 11.64±5.21 $x10^{9}$/l while that of control broilers ranged from 3.60 $x10^{9}$/l to 10.40 $x10^{9}$/l with a mean and standard deviation of 9.68±5.77 $x10^{9}$/l (Table 2). The Haemoglobin (Hb) concentration of four weeks old experimental broiler ranged from 5.30 g/dl to 6.90 g/dl with a mean and standard deviation of 6.48±0.67 g/dl while that of control broilers ranged from 6.30 g/dl to 9.00 g/dl with a mean and standard deviation of 7.26±0.67 g/dl. The Mean Corpuscular Volume (MCV) of four weeks old experimental broiler ranged from 40.00 fl to 69.00 fl with a mean and standard deviation of 51.60±12.10 fl while that of control broilers ranged from 47.00 fl to 70.00 fl with a mean and standard deviation of 56.00±12.94 fl. The Mean Corpuscular Haemoglobin (MCH) of four weeks old experimental broiler ranged from 13.00 pg to 22.00 pg with a mean and standard deviation of 16.80±4.09 pg while that of control broilers ranged from 12.00 pg to 23.00 pg with a mean and standard deviation of 18.00±4.06 pg (Table 2). The Mean

Corpuscular Haemoglobin Concentration (MCHC) of four weeks old experimental broiler was 33.00 g/dl while that of control broilers was 33.00 g/dl. The ESR of four weeks old experimental broiler ranged from 4.00 % to 7.50 % with a mean and standard deviation of 5.72±1.70 % while that of control broilers ranged from 3.90 % to 6.60 % with a mean and standard deviation of 5.02±1.03 % (Table 2). The student's T-test result showed that the differences in mean values for the blood parameters of four weeks old experimental and control broilers were not significant at p=0.05 (Table 2).

The PCV of six weeks old experimental broiler ranged from 19.00 % to 24.00 % with a mean and standard deviation of 21.20±1.92 % while that of control broilers ranged from 21.00 % to 25.00 % with a mean and standard deviation of 22.60±1.67 % (Table 3). The RBC count of six weeks old experimental broiler ranged from 2.68 $x10^{12}$/l to 4.28 $x10^{12}$/l with a mean and standard deviation of 3.69±0.66 $x10^{12}$/l while that of control broilers ranged from 3.28 $x10^{12}$/l to 5.16 $x10^{12}$/l with a mean and standard deviation of 4.32±0.76 $x10^{12}$/l (Table 3). The WBC count of six weeks old experimental broiler ranged from 6.00 $x10^{9}$/l to 20.80 $x10^{9}$/l with a mean and standard deviation of 16.72±6.10 $x10^{9}$/l while that of control broilers ranged from 8.40 $x10^{9}$/l to 16.20 $x10^{9}$/l with a mean and standard deviation of 11.34±3.11 $x10^{9}$/l (Table 3). The Hb concentration of six weeks old experimental broiler ranged from 6.30 g/dl to 8.00 g/dl with a mean and standard deviation of 7.08±0.65 g/dl while that of control broilers ranged from 6.90 g/dl to 8.30 g/dl with a mean and standard deviation of 7.50±0.57 g/dl (Table 3). The MCV of six weeks old experimental broiler ranged from 49.00 fl to 70.00 fl with a mean and standard deviation of 52.80±8.21 fl while that of control broilers ranged from 46.00 fl to 64.00 fl with a mean and standard deviation of 58.00±7.12 fl (Table 3). The MCH of six weeks old experimental broiler ranged from 16.00 pg to 23.00 pg with a mean and standard deviation of 17.40±2.74 pg while that of control broilers ranged from 16.00 pg to 21.00 pg with a mean and standard deviation of 19.00±2.30 pg (Table 3). The MCHC of six weeks old experimental broiler was 33.00 g/dl while that of control broilers was 33.00 g/dl (Table 3). The ESR of six weeks old experimental broiler ranged from 2.80 % to 6.60 % with a mean and standard deviation of 4.12±1.45 % while that of control broilers ranged from 4.00 % to 10.90 % with a mean and standard deviation of 6.46±2.66 % (Table 3). The neutrophils of six weeks old experimental broiler ranged from 36.00 % to 48.00 % with a mean and standard deviation of 41.40±4.69 % while that of control broilers

ranged from 36.00 % to 49.00 % with a mean and standard deviation of 40.00±5.13 % (Table 3). The lymphocytes of six weeks old experimental broiler ranged from 60.00 % to 62.00 % with a mean and standard deviation of 60.80±0.84 % while that of control broilers ranged from 50.00 % to 63.00 % with a mean and standard deviation of 57.80±5.26 % (Table 3). The monocytes of six weeks old experimental broiler ranged from 0.00 % to 2.00 % with a mean and standard deviation of 1.00±1.00 % while that of control broilers ranged from 0.00 % to 1.00 % with a mean and standard deviation of 0.80±0.45 % (Table 3). The eosinophil of six weeks old experimental broiler and control broilers was 0.00 % (Table 3). The student's T-test result showed that the differences in mean values for the blood parameters of six weeks old experimental and control broilers were not significant at p=0.05 (Table 3).

The PCV of eight weeks old experimental broiler ranged from 21.00 % to 25.00 % with a mean and standard deviation of 23.80±1.78 % while that of control broilers ranged from 22.00 % to 26.00 % with a mean and standard deviation of 24.00±1.58 % (Table 4). The RBC count of eight weeks old experimental broiler ranged from 2.82 $x10^{12}$/l to 6.02 $x10^{12}$/l with a mean and standard deviation of 4.72±1.18 $x10^{12}$/l while that of control broilers ranged from 3.34 $x10^{12}$/l to 5.96 $x10^{12}$/l with a mean and standard deviation of 4.72±1.01 $x10^{12}$/l (Table 4). The WBC count of eight weeks old experimental broiler ranged from 5.80 $x10^{9}$/l to 8.20 $x10^{9}$/l with a mean and standard deviation of 8.56±1.00 $x10^{9}$/l while that of control broilers ranged from 5.40 $x10^{9}$/l to 10.20 $x10^{9}$/l with a mean and standard deviation of 6.88±1.92 $x10^{9}$/l (Table 4). The Hb concentration of eight weeks old experimental broiler ranged from 7.00 g/dl to 8.30 g/dl with a mean and standard deviation of 7.92±0.58 g/dl while that of control broilers ranged from 7.30 g/dl to 8.70 g/dl with a mean and standard deviation of 8.00±0.54 g/dl (Table 4). The MCV of eight weeks old experimental broiler ranged from 41.00 fl to 74.00 fl with a mean and standard deviation of 51.80±12.72 fl while that of control broilers ranged from 41.00 fl to 65.00 fl with a mean and standard deviation of 52.20±8.90 fl (Table 4). The MCH of eight weeks old experimental broiler ranged from 13.00 pg to 24.00 pg with a mean and standard deviation of 16.80±4.18 pg while that of control broilers ranged from 13.00 pg to 21.00 pg with a mean and standard deviation of 17.00±2.95 pg (Table 4). The MCHC of eight weeks old experimental broiler was 33.00 g/dl while that of control broilers was also 33.00 g/dl (Table 4). The ESR of eight weeks old experimental broiler ranged from 3.20 % to 5.20 % with a

mean and standard deviation of 3.92±0.83 % while that of control broilers ranged from 3.20 % to 3.90 % with a mean and standard deviation of 3.90±0.30 % (Table 4). The neutrophils of eight weeks old experimental broiler ranged from 31.00 % to 60.00 % with a mean and standard deviation of 51.80±12.10 % while that of control broilers ranged from 44.00 % to 64.00 % with a mean and standard deviation of 45.40±8.73 % (Table 4). The lymphocytes of eight weeks old experimental broiler ranged from 40.00 % to 69.00 % with a mean and standard deviation of 54.60±12.10 % while that of control broilers ranged from 36.00 % to 56.00 % with a mean and standard deviation of 48.00±8.60 % (Table 4). The monocytes of eight weeks old experimental broiler was 0.00 % while that of control broilers ranged from 0.00 % to 1.00 % with a mean and standard deviation of 0.20±0.45 % (Table 4). The eosinophils of eight weeks old experimental broiler and control broilers was 0.00 % (Table 4). The student's T-test result showed that the differences in mean values for the blood parameters of eight weeks old experimental and control broilers were not significant at p=0.05 (Table 4).

The red blood indices like PCV, RBC count, Hb concentration, MCV and MCH were significantly reduced (p=0.05) in the blood of the four, six and eight weeks old experimental broilers than those of control broilers. MCHC had the same value as that of control broilers while WBC count, heterophilis, lymphocytes, monocytes and ESR were significantly higher than those of control broiler chicks (Tables 2 - 5). The mean values of all the haematological parameters of the experimental and control broilers irrespective of their age showed that the PCV, RBC, WBC, Hb, MCV, MCH, Neutrophils, Lymphocytes and ESR of the experimental broilers were significantly different from those of the control while the MCHC, monocytes and eosinophil were not significantly different (Table 5).

4.8.2 Haematological Values of the Blood of Free-Range Local Ori-Ile Chicks

The results of the haematological parameters of the eight-week old free-range Ori-Ile Olodo chicks compared with the control are shown in Tables 6. The PCV of eight-week old free-range Ori-Ile Olodo chicks ranged from 23.00 % to 32.00 % with a mean and standard deviation of 23.50±4.50 % while that of control free-range chicks ranged from 15.00 % to 32.00 % with a mean and standard deviation of 25.25±12.02

% (Table 6). The RBC count of eight-week old free-range Ori-Ile Olodo chicks ranged from 3.80 $x10^{12}$/l to 5.16 $x10^{12}$/l with a mean and standard deviation of 4.39±0.60 $x10^{12}$/l while that of control free-range chicks ranged from 6.22 $x10^{12}$/l to 7.22 $x10^{12}$/l with a mean and standard deviation of 6.72±0.71 $x10^{12}$/l (Table 6).

The WBC count of eight-week old free-range Ori-Ile Olodo chicks ranged from 4.80 $x10^{9}$/l to 8.80 $x10^{9}$/l with a mean and standard deviation of 8.55±1.91 $x10^{9}$/l while that of control free-range chicks ranged from 6.90 $x10^{9}$/l to 10.20 $x10^{9}$/l with a mean and standard deviation of 7.33±2.33 $x10^{9}$/l (Table 6). The Hb concentration of eight-week old free-range Ori-Ile Olodo chicks ranged from 7.60 g/dl to 10.60 g/dl with a mean and standard deviation of 7.90±1.47 g/dl while that of control free-range chicks ranged from 5.10 g/dl to 10.70 g/dl with a mean and standard deviation of 8.40±3.96 g/dl (Table 6). The MCV of eight-week old free-range Ori-Ile Olodo chicks ranged from 50.00 fl to 62.00 fl with a mean and standard deviation of 57.00±5.29 fl while that of control free-range chicks ranged from 51.00 fl to 67.00 fl with a mean and standard deviation of 59.00±11.31 fl (Table 6).

The MCH of eight-week old free-range Ori-Ile Olodo chicks ranged from 16.00 pg to 20.00 pg with a mean and standard deviation of 18.75±1.89 pg while that of control free-range chicks ranged from 17.00 pg to 22.00 pg with a mean and standard deviation of 19.50±3.54 pg (Table 6). The MCHC of eight-week old free-range Ori-Ile Olodo chicks was 33.00 g/dl while that of control free-range chicks was also 33.00 g/dl (Table 6). The ESR of eight-week old free-range Ori-Ile Olodo chicks ranged from 1.20 % to 4.80 % with a mean and standard deviation of 3.05±1.47 % while that of control free-range chicks ranged from 1.60 % to 8.10 % with a mean and standard deviation of 4.85±4.60 % (Table 6). The neutrophils of eight-week old free-range Ori-Ile Olodo chicks ranged from 49.00 % to 62.00 % with a mean and standard deviation

Table 4.1: Haematological Parameters in four (4) weeks old Broiler Chicks

Sample	PCV (%) (4wks)	RBC ($x10^{12}$/l) (4wks)	WBC ($x10^{9}$/l) (4wks)	HB (g/dl) (4wks)	MCV (fl) (4wks)	MCH (Picogram (pg) (4wks)	MCHC (g/dl) (4wks)	ESR (%) (4wks)
Expt.	19.6000±2.0740	3.5800±0.7555	11.6400±5.2123	6.4800±0.6723	51.6000±12.0950	16.8000±4.0870	33.0000±0	5.7200±1.6950
Control	21.8000±3.2710	4.2440±0.4080	9.6800±5.7717	7.2600±1.0831	56.0000±12.9420	18.0000±4.0620	33.0000±0	5.0200±1.0310
t-value	-1.2700	-1.7290	0.5640	-1.3680	0.5550	0.4660	-	0.7890

Each value is a mean of 5 determinations ± S.D

t-values with * are significant at P = 0.05

Table 4.2: Haematological Parameters in Six (6) Weeks Old Broiler Chicks

Sample	PCV (%) (6wks)	RBC ($x10^{12}$/l) (6wks)	WBC ($x10^{9}$/l) (6wks)	HB (g/dl) (6wks)	MCV (fentolitres) (fl) (6wks)	MCH ((Picogram) (pg) (6wks)	MCHC (g/dl) (4wks)	Neutrophils (%) (6wks)	LYMP (%) (6wks)
Expt.	21.2000±1.9240	3.6920±0.6590	16.7200±6.1020	7.0800±0.6530	52.8000±8.2160	17.4000±2.7390	33.000 0±0	41.4000±4.6900	60.8000±0.8370
Control	22.6000±1.6730	4.3240±0.7616	11.3400±3.1090	7.5000±0.5700	58.0000±7.1200	19.0000±2.3020	33.000 0±0	40.0000±5.1280	57.8000±5.2630
t-value	-1.2280	-1.4030	1.7570	-1.0830	1.0690	1.0000	-	-0.4500	1.2590

Sample	MONO (%) (6wks)	EOS (%) (6wks)	ESR (%) (6wks)
Expt.	1.0000±1.0000	0	4.1200±1.4533
Control	0.8000±0.4470	0	6.4600±2.6557
t-value	0.4080	-	-1.7280

Each value is a mean of 5 determinations ± S.D

t-values with * are significant at P = 0.05

Table 4.3: Haematological Parameters in Eight (8) Weeks Old Broiler Chicks

Sample	PCV (%) (8wks)	RBC ($x10^{12}$/l) (8wks)	WBC ($x10^{9}$/l) (8wks)	HB (g/dl) (8wks)	MCV (fento litres) (fl) (8wks)	MCH (Picogram) (pg) (8wks)	MCHC (g/dl) (4wks)	Neutrophils (%) (8wks)	LYMP (%) (8wks)
Expt.	23.8000±1.7890	4.7200±1.1763	8.5600±0.9960	7.9200±0.5762	51.8000±12.7160	16.8000±4.1830	33.0000±0	51.8000±12.0950	54.6000±12.0950
Control	24.0000±1.5810	4.7236±1.0077	6.8800±1.9204	8.0000±0.5385	52.2000±8.8990	17.0000±2.9500	33..0000±0	45.4000±8.7290	48.0000±8.6020
t-value	-0.1870	0.0230	-1.7360	-0.2270	0.0580	0.0870	-	-0.9590	0.9940

Sample	MONO (%) (8wks)	EOS (%) (8wks)	ESR (%) (8wks)
Expt.	0	0	3.9200±0.8349
Control	0.2000±0.4470	0	3.5000±0.3000
t-value	-1.0000	-	1.0590

Each value is a mean of 5 determinations ± S.D

t-values with * are significant at P = 0.05

Table 4.4: Mean Haematological Parameter between Experimental and Control Broilers

Exposure	PCV (%)	RBC ($x10^{12}$ /l)	WBC ($x10^{9}$/l)	HB (g/dl)	MCV (fl)	MCH (pg)	MCHC (g/dl)	Neutrophils (%)
Expt.	21.5333± 2.53[a]	4.0027± 0.99[a]	11.7470± 6.00[a]	7.1600± 0.85[a]	52.067± 10.93[a]	17.000± 3.55[a]	33.0000± 0.00[a]	31.0670± 23.78[a]
Control	22.8000± 2.33[b]	4.4293± 0.74[b]	9.8600 ± 3.84[b]	7.5867± 0.78[b]	55.400± 8.90[b]	18.000± 2.97[b]	33.0000± 0.00[a]	28.4670± 22.08[b]
Mean [2]	12.0333	1.3653	26.6963	1.3653	83.3333	7.5000	0	50.7000

Exposure	Lymp (%)	Mono (%)	Eos (%)	ESR (%)
Expt.	35.2670±26.69[a]	0.3333±0.72[a]	0.0000±0.00[a]	4.5867±1.52[a]
Control	38.4670±29.01[b]	0.3333±0.49[a]	0.0000±0.00[a]	4.9933±1.98[b]
Mean [2]	76.8000	0	0	1.2403

Each value is a mean of 15 determinations ± S.D

t-values with * are significant at P = 0.05

Column values with different superscripts are significantly (p=0.05) different

Table 4.5: Haematological Parameters in Free-Range Local Ori-Ile Chicks

Sample	PCV (%) (loc)	RBC ($x10^{12}$/l) (loc)	WBC ($x10^{9}$/l) (loc)	HB (g/dl) (loc)	MCV (fl) (loc)	MCH (pg) (loc)	MCHC (g/dl) (loc)	Neutrophils (%) (loc)
Expt.	23.5000 ±4.5000	4.3900 ±0.6034	8.5500 ±1.9068	7.9000 ±1.4674	57.0000 ±5.2920	18.7500 ±1.8930	33.0000 ±0	54.0000 ±5.4770
Control	25.2500 ±12.0210	6.7200 ±0.7071	7.3250 ±2.3335	8.4000 ±3.9598	59.0000 ±11.3140	19.5000 ±3.5360	33.5000 ±0.7070	56.0000 ±7.0710
t-value	0.2820	-4.2640*	-0.7000	0.2450	-0.3170	-0.3590	-1.6330	0.3900

Sample	LYMP (%) (loc)	MONO (%) (loc)	EOS (%) (loc)	ESR (%) (loc)
Expt.	46.0000±5.6200	0	0	3.0500±1.4708
Control	43.7500±7.071	0	0	4.8500±4.5962
t-value	-0.4320	-	-	-0.7910

Each value is a mean of 5 determinations ± S.D

t-values with * are significant at P = 0.05

of 54.00±5.48 % while that of control free-range chicks ranged from 49.00 % to 59.00 % with a mean and standard deviation of 56.00±7.07 % (Table 6). The lymphocytes of eight-week old free-range Ori-Ile Olodo chicks ranged from 38.00 % to 51.00 % with a mean and standard deviation of 46.00±5.62 % while that of control free-range chicks ranged from 41.00 % to 51.00 % with a mean and standard deviation of 43.75±7.07 % (Table 6). The monocytes of eight-week old free-range Ori-Ile Olodo chicks and the control free-range chicks were 0.00 % (Table 6). The eosinophils of eight-week old free-range Ori-Ile Olodo chicks and control broilers were 0.00 % (Table 6). The student's T-test result showed that the differences in mean values for the blood parameters of eight weeks old free-range Ori-Ile Olodo chicks and control free-range chicks were not significant at p=0.05except RBC (Table 6).

The red blood indices like PCV, RBC count, Hb concentration, MCV, MCH, MCHC, lymphocytes, heterophilis and ESR were significantly reduced (p=0.05) in the blood of the eight-week old free-range Ori-Ile Olodo chicks than those of control. Monocytes and eosinophils had the same value as those of control while WBC count was significantly higher than those of control chicks (Tables 6).

4.9 Histopathology of the Liver and Kidney of Broilers and Free-Range Local Chicks

The results of the histopathological properties of the liver and kidney of broilers and free-ranged local Ori-Ile Olodo chicks compared to their respective controls are presented below:

4.9.1 Histopathology of the Liver and Kidney of Experimental Broilers

The result obtained showed that the unexposed two weeks old broilers' liver and kidney had no traces of histological changes (Plate 6), whilst the four, six and eight weeks old broilers' liver and kidney showed significant number of histological changes.

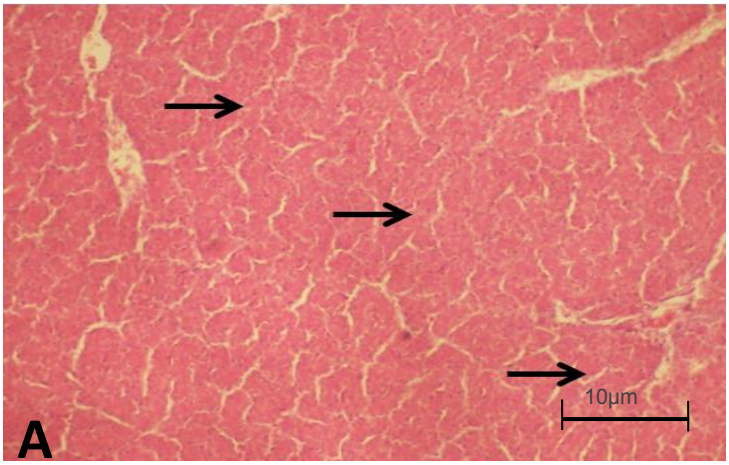
In the four weeks old broilers, the liver showed cases of diffuse vacuolar degeneration with areas of necrotic hepatocytes and loci of cellular aggregation by mononuclear cells (Plate 7) while the kidney showed mild interstitial congestion though no visible leision was seen (Plate 8).

In the six weeks old broilers, the liver had central venous and portal congestion. It also had portal fibrosis as well as cases of mild cellular infiltration with areas of severe diffuse hepatic degeneration and necrosis (Plate 9) while the kidney showed mild renal cortical congestion though no visible leision was seen as well (Plate 10).

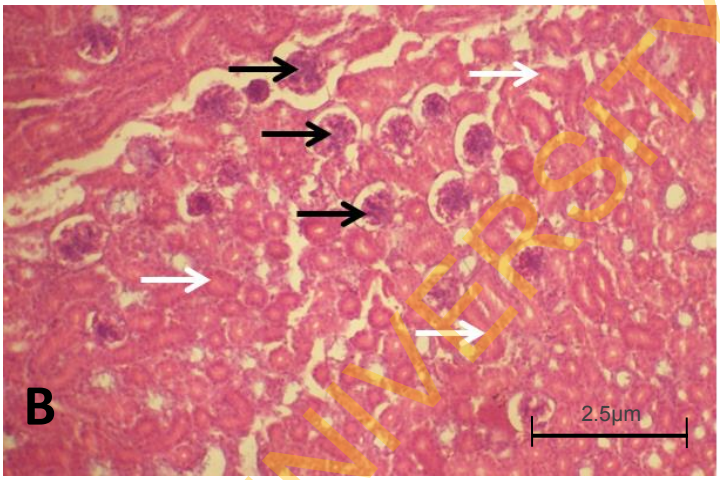
In the eight weeks old broilers, the liver had loci of severe cellular aggregation by macrophages and lymphocytes as well as mild periportal hepatic degeneration. It also had necrosis with very mild cellular infiltration by mononuclear cells (Plate 11) while the kidney had fibrosis at the interstitium and very much reduced tubular lumen. The kidney also showed multiple foci of tubular necrosis with severe cellular infiltration (Plate 12).

4.9.2 Histopathology of the Liver and Kidney of Free-Range Local Ori-Ile Olodo Chicks

The results obtained showed that the liver of the free-range local chicks showed cases of masssive perivascular cellular infiltration by mononuclear cells and severe diffuse hepatic degeneration as well as necrosis (Plate 13) while their kidney had severe renal cortical congestion with massive interstitial haemorrhages of the renal cortex (Plate 14).

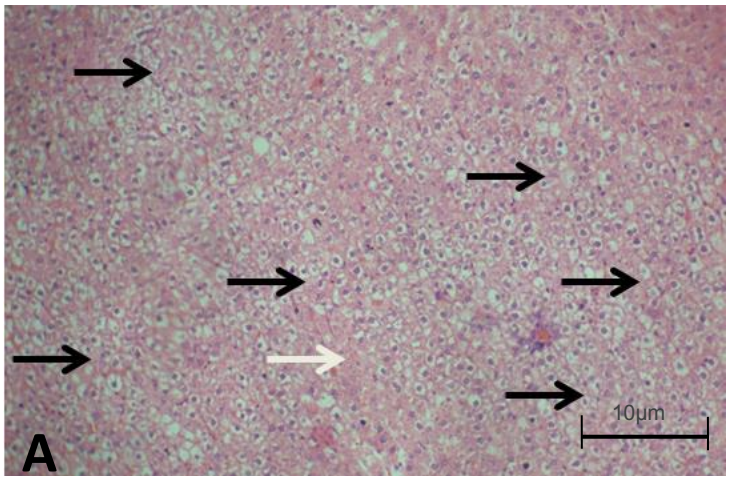


Pre-assessed liver showing normal hepatic chords in radial arrangements (arrows).

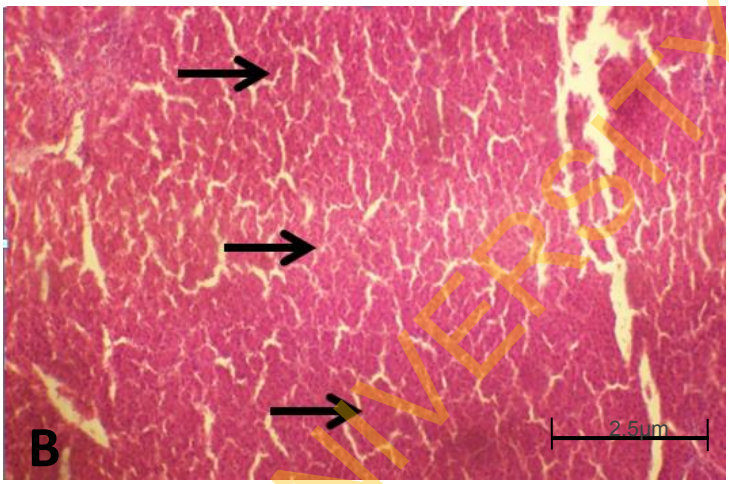


Pre-assessed kidney showing normal glomeruli (black arrows) and renal tubules (white arrows) at the cortical region.

Plate 4.1: Photomicrograph of the unexposed broilers' liver (A) and kidney (B) at 2 weeks

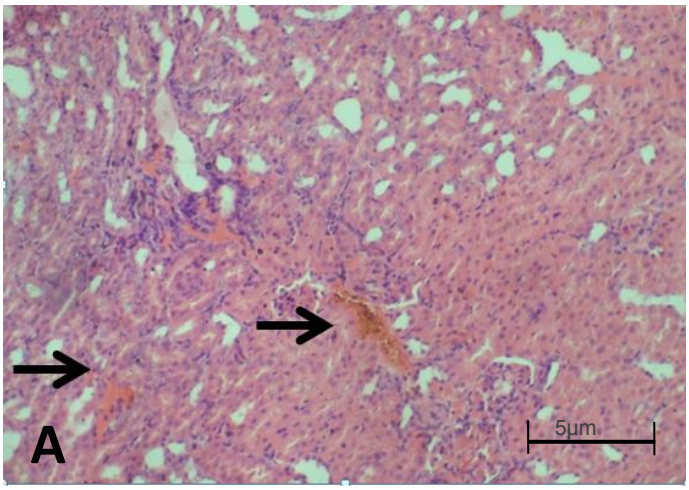


Exposed B- liver (4 weeks old) showing diffuse vacuolar degeneration (black arrows), necrotic hepatocytes (white arrows).

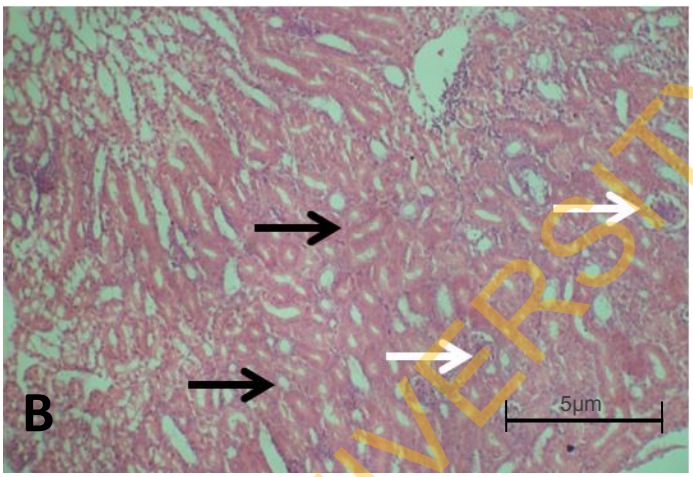


Control B-liver (4 weeks old) showing normal hepatic chords (arrows) in radial arrangements.

Plate 4.2: Photomicrograph of the exposed (A) and control (B) broilers' liver at 4 weeks

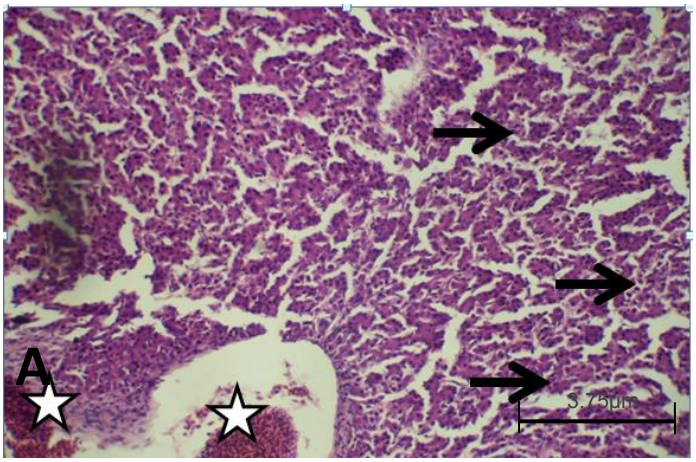


Exposed B-kidney (4 weeks old) showing mild interstitial congestion (arrows).

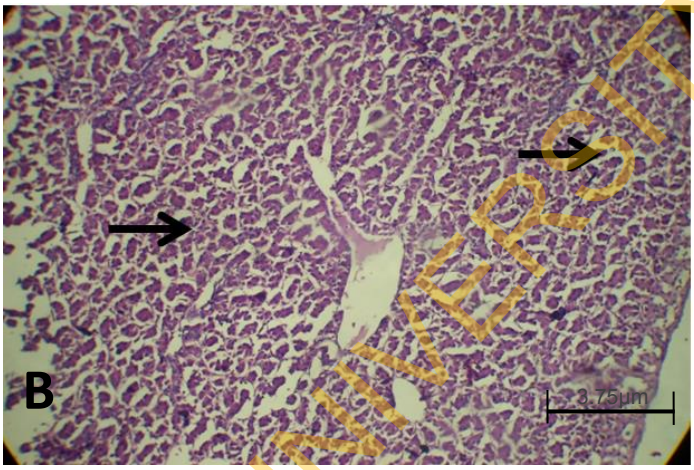


Control B-kidney (4 weeks old) showing normal glomeruli (white arrows) and renal tubules (black arrows) at the cortical region.

Plate 4.3: Photomicrograph of the exposed (A) and Control (B) broilers' kidney at 4 weeks old

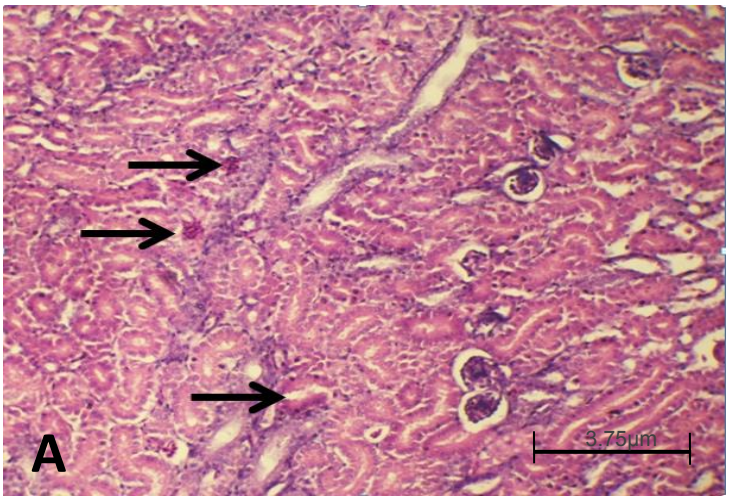


Exposed B- liver (6 weeks old) showing central venous and portal congestion (white star), portal fibrosis, mild cellular infiltration, severe diffuse hepatic degeneration and necrosis (black arrows).

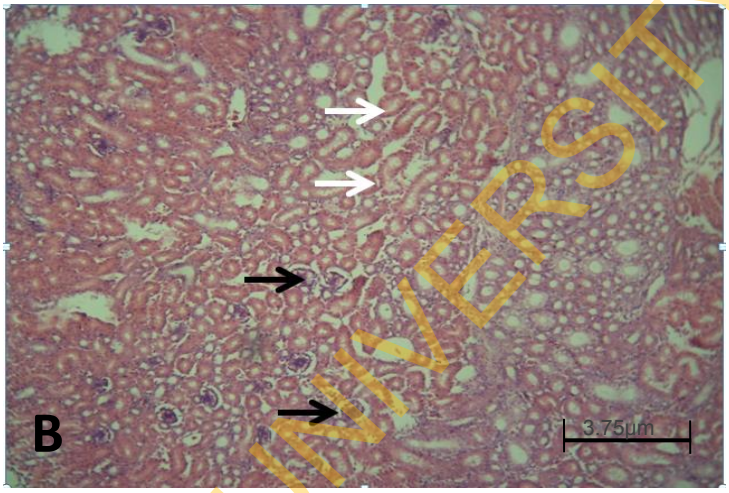


Control B-liver (6 weeks old) showing normal hepatic chords (arrows).

Plate 4.4: Photomicrograph of the exposed (A) and Control (B) broilers' liver at 6 weeks

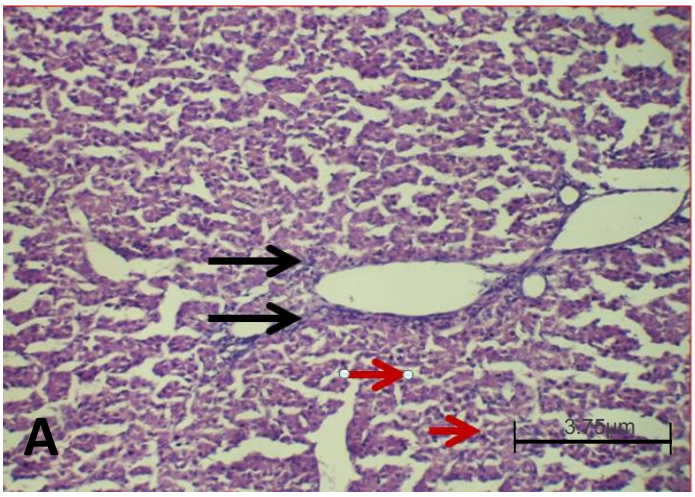


Exposed B-kidney (6 weeks old) showing mild renal cortical congestion (arrows).

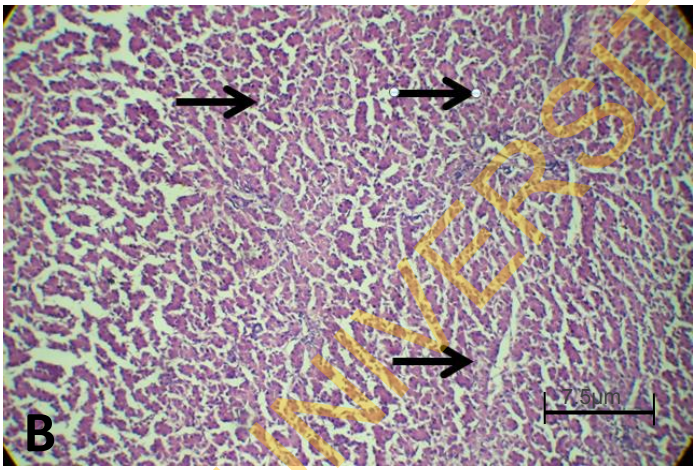


Control B-kidney (6 weeks old) showing normal glomeruli (black arrows) and renal tubules (white arrows) at the cortical region.

Plate 4.5: Photomicrograph of the exposed (A) and Control (B) broilers' kidney at 6 weeks

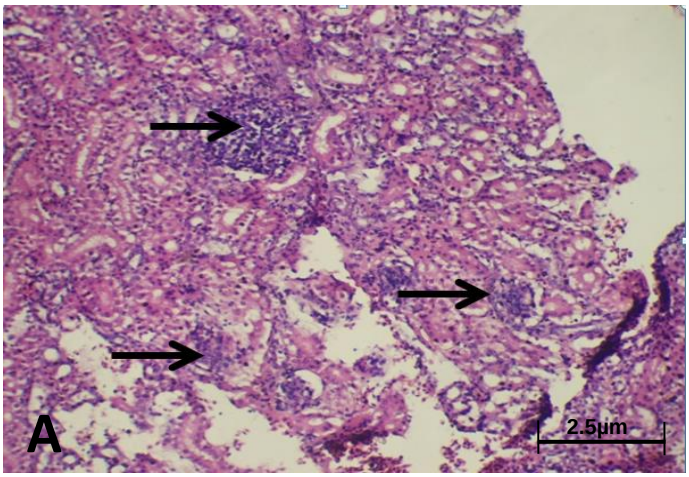


Exposed B- liver (8 weeks old) showing loci of severe cellular aggregation by macrophages and lymphocytes (black arrows); mild periportal hepatic degeneration, necrosis with mild cellular Infiltration by mononuclear cells (red arrows).

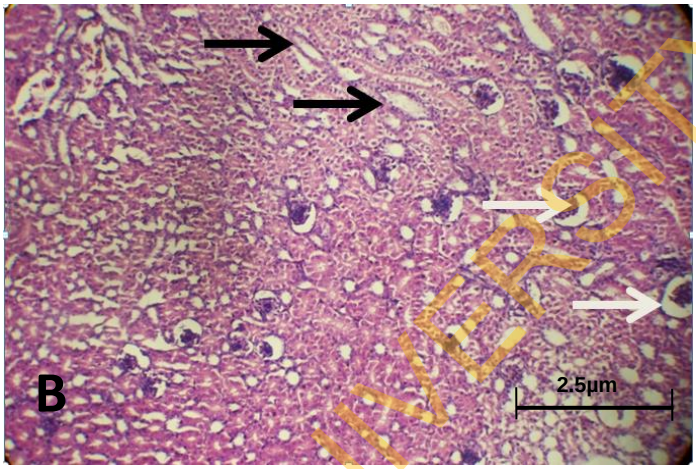


Control B-liver (8 weeks old) showing normal hepatic chords (black arrows).

Plate 4.6: Photomicrograph of the exposed (A) and Control (B) broilers' liver at 8 weeks

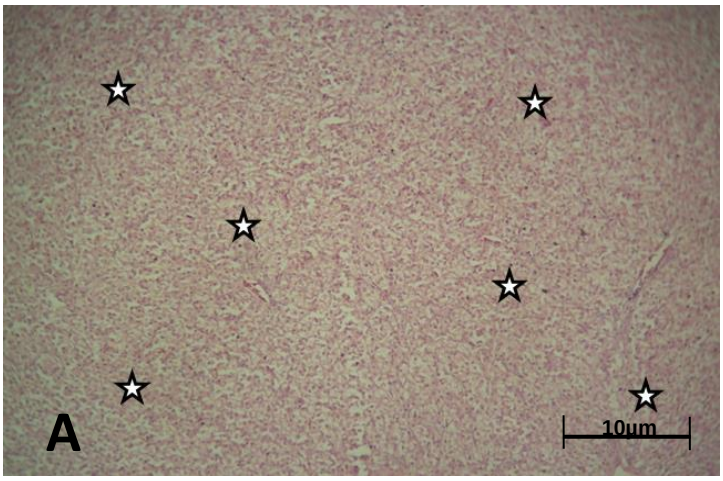


Exposed B-kidney (8 weeks old) showing multiple foci of tubular necrosis with severe cellular infiltration (Arrows).

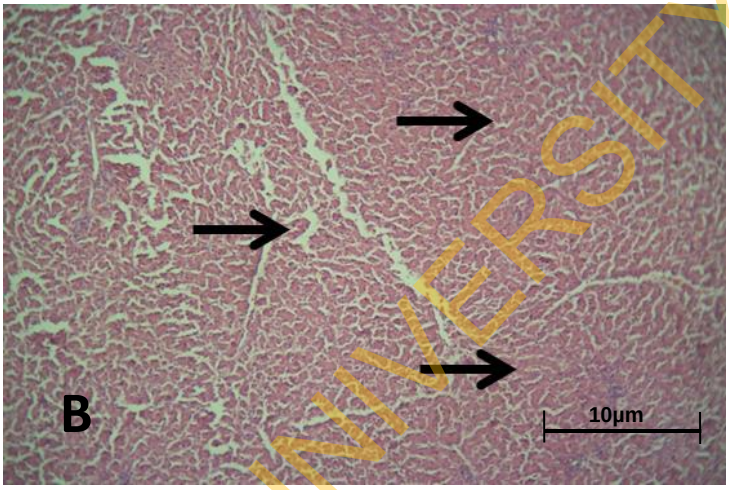


Control B-kidney (8 weeks old) showing normal glomeruli (black arrows) and renal tubules (white arrows) at the cortical region.

Plate 4.7: Photomicrograph of the exposed (A) and Control (B) broilers' kidney at 8 weeks

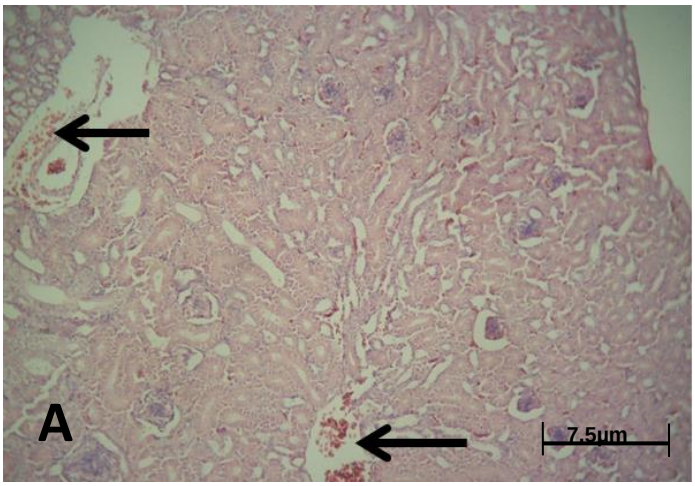


Exposed L- liver showing diffuse hepatic degeneration and necrosis (stars).

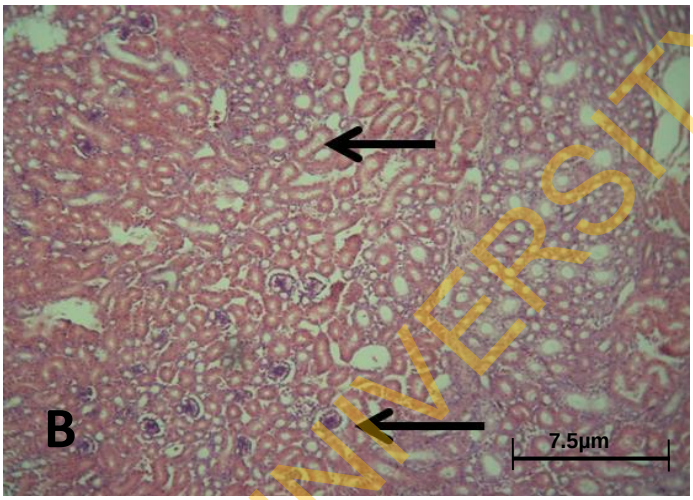


Control L-liver showing normal hepatic chords (black arrows).

Plate 4.8: Photomicrograph of the exposed (A) and Control (B) Free-range local (L) chicks' liver at 8 weeks



Exposed L-kidney showing renal cortical congestion and interstitial hemorrhages (arrows).



Control L-kidney showing normal glomeruli and renal tubules at the cortical region (arrows).

Plate 4.9: Photomicrograph of the exposed (A) and Control (B) free-range local (L) chicks' kidney at 8 weeks

CHAPTER FIVE

DISCUSSION

5.1 Lead, Cadmium and Iron Concentrations in Topsoil Samples

5.1.1 Lead

Lead (Pb) also ranks number two on the list of "top twenty hazardous substances" list (Roberts, 1999) and is also a significant source of most human heavy metal poisoning. The target organs are usually the bones, brain, blood, kidneys and thyroid gland (International Occupational Safety and Health Information Centre, 1999). The resultant symptoms of exposure to chronic levels of lead such as back pain, anxiety, behavioral disorder, co-ordination and concentration loss, emotional instability, muscle weakness and aches, pregnancy abortion, infant growth disorders among others; are non-disputable in this type of pollution incidence.

This study has revealed that lead concentrations in the topsoil of the waste dumpsite and those of distances 0 m to 25 m along the gradient point directions North, South, East and West from the edge of the waste dumpsite were significantly higher than the values obtained from the control topsoil. In fact, the lead concentrations obtained were several folds higher than the maximum permissible limit of 164mg/kg by NESREA (2011). Although, lead occurs naturally in all soils in concentrations ranging from 1 to 200 mg/kg with a mean of 15 mg/kg (Chirenje *et al.*, 2004; Oni, 2010); the values obtained in this study for topsoil of the waste dumpsite and those of distances 0 m to 25 m along the gradient point directions North, South, East and West from the edge of the waste dumpsite were several times beyond this range.

According to WHO (1989), normal concentrations of lead in soil range from 15 to 30 mg/kg; roadside soils can reach 5000 mg/kg and soils from industrial sites may exceed 30 000 mg/kg. This study lead values were much higher than the value for normal soil lead concentrations and roadside lead values but were much lower than values stated for industrial sites. Also, this study lead values were higher than 1000 mg/kg of soil Pb defined by US. EPA (1994) as level that correlates with the life-threatening blood level of 7µgdL^{-1}. Hence, this suggests a high level of contamination of the topsoil of the study site.

Similarly, the values obtained for soil lead in this study were several folds beyond the different recommended background levels in literature. WHO (1995) reported the background levels of lead in soil to range between 10 and 70 mg/kg with a mean level near roadways of 138 mg/kg. In tropical soils of Nigeria, depending on the underlying bedrock type, the background trace element content of lead ranges from 16 - 124mg/kg with a mean value of 42mg/kg in some parts as well as 35 - 150mg/kg with a mean value of 78mg/kg at other parts (Olade, 1987). Studies by Tijani *et al* (2006) reported that the background values of lead in soils of Ibadan ranged from 20.8 - 65.3 mg/kg based on the type of bedrock while Adie and Osibanjo (2009) stated that control soil samples of their study on assessment of soil pollution by slag from an automobile battery manufacturing plant in Nigeria showed very low background levels of Pb ranging from 2.50 - 11.00 mg/kg.

In addition, the soil lead values obtained in this study were compared with those obtained in the previous studies conducted on areas polluted with battery wastes in Nigeria, especially those studies carried out in other parts of Olodo with similar battery waste dumping sites. The soil mean lead values obtained in this study were higher than the mean lead level of 50 - 2000 mg/kg obtained by Onianwa and Fakayode (2000) in their study on lead contamination of topsoil and vegetation in the vicinity of a battery factory in Nigeria. However, the mean values in this study compare significantly with the range of 243 - 126000 mg/kg reported for lead concentration by Adie and Osibanjo's (2009) studies on soil polluted by slag from an automobile battery manufacturing plant in Nigeria; the range of 419.54 - 10630.04 mg/kg reported in the studies conducted by Oyediran and Aladejana (2011) on impact assessment and safety status of the excavated waste site at Olodo, Ibadan, Nigeria, and the range of 39.4 -

9652.0 mg/kg was reported by Sridhar *et al* (2012) from the topsoil samples of other areas of Olodo, Ibadan. However, the values obtained in this study were less than the mean lead range of 71830 - 72130 mg/kg obtained by Olusoga and Osibanjo (2007) from topsoil samples taken from an abandoned dumpsite of a lead-battery manufacturing company at the same Olodo in Nigeria.

Similarly, the range of lead concentrations obtained in these results were extremely higher than EU upper limit of 300 mg/kg and maximum tolerable levels of 90 – 300 mg/kg proposed for agricultural soil (European commission, 1986; Kabata-Pendias, 1984). Likewise, US. EPA (2008) stated that Pb is considered a hazard when it is equal to or exceeds 400 mg/kg in bare soil. The maximum values of lead that were measured in all the locations in this study were much higher than 400 mg/kg.

The concentration of lead in this study were also compared to those found in several other studies done on soils from either municipal waste dumpsites, highways, residential areas, gardens, industrial areas, among others. The values obtained in this study were higher than the mean lead levels of 0.01 mg/kg - 26.60 mg/kg in soils of Ota metropolis, Ogun State, Nigeria reported by Olukanmi and Adebiyi (2012); 143.2 mg/kg in soil around Ikeja industrial estate, Lagos, Nigeria by Fakayode and Onianwa (2002); 0.2 - 3.9 µg/g (mg/kg) in soils around lake Victoria, Kisumu, Kenya by Makokha *et al* (2008); 3.42 - 7.67 mg/kg in soil samples studied in the evaluation of groundwater and soil pollution in a landfill area using electrical resistivity imaging survey by Ahmed and Suleiman (2001); 63.4 - 72.1 mg/kg in soils studied in the study of the long-term effect of municipal waste disposal on soil properties and productivity of sites used for urban agriculture in Abakaliki, Nigeria by Anikwe and Nwobodo (2002); 146 - 210 mg/kg in agricultural soils located near a solid waste dumpsite in Gaza Strip obtained by Shomar *et al* (2005); 6.0 - 245.0 µg/g (mg/kg) in the studies of soil quality around a solid waste dumpsite in Port-Harcourt, Nigeria by Ideriah *et al* (2006); 17.0 - 23.5 mg/kg in studies of Eddy *et al* (2006) on elemental composition of soil in some dumpsites; 161.47 - 570.14 mg/kg in Waste Dump Area topsoil samples and 0 - 163.06 mg/kg in Leachate Lagoon Area topsoil samples studied by Oni (2010) in Aba Eku landfill site, Ibadan, Nigeria and 22.47±0.58ug/g obtained by Nsikak (2006) in cultivated floodplain ultisol of Cross-River, Nigeria. However, the results compare significantly with the range of 18.25 - 15100 mg/kg obtained for lead

concentration in topsoil studied at automobile mechanic villages in Ibadan, Nigeria by Adelekan and Abegunde (2011) and were considerably less than 10,000 mg/kg found in top-soils in a village in Zamfara State, Nigeria by Purefoy, (2010). Curtis and Smith (2002) confirmed that urban soils often contain high lead concentrations, up to 1840 mg/kg or more and this is often due to past uses of lead in industrial processes and consumer products.

Comparing the different individual values obtained in this study with those values set as limits in some other countries, they are several multiples higher than the set maximum limits for lead by Luxembourg and United Kingdom (300 mg/kg), Austria and France (100 mg/kg), Germany (70 mg/kg) as well as Netherlands and Sweden (40 mg/kg). This further indicates an excessive as well as potently dangerous level of Pb in those analyzed soil samples and as such, there is need to regulate it to lower and more tolerable levels.

In all of the gradient points sampled around the waste dumpsite, it was realized that distance 0 m - 10 m had higher lead concentrations than the value obtained on the waste dumpsite while distances beyond 10 m up to 25 m had a little less than that of the waste dumpsite. Since distance 0 m along any of the gradient points represents the beginning of the rectangular waste dumpsite, the higher lead concentrations could be due to direct waste dumping activities. However, being the closest part of the waste dumpsite to the road network in the area, additional deposit could originate from the automobiles patronizing the area. Similarly, the high concentration along the gradient points studied beyond distance 0 m may be as a result of direct deposition by the same waste disposing agents. This is further corroborated by the observation of the presence of battery cases and pieces of weathered slag, which were found scattered everywhere and seen in areas around the site.

Finally, the elevated Pb levels in this study may be primarily due to battery waste disposal. The high lead concentrations from the result of the analysis of the topsoil samples in the study further suggest that lead is a prominent component of most battery waste and it is a significant pollutant of community surrounding Ori-Ile waste dumpsite. The observed very high concentration of lead in the top layers of the soil also showed that lead is especially prone to accumulation in surface horizons of soil. According to Davies (1995), this may be due to its low water solubility which may

result in very low mobility. Furthermore, it is reasonable to deduce that the disposal of battery wastes was not just carried out on the waste dumpsite alone but in several other parts of the community, hence, resulting in a widespread distribution of the pollutants in the waste across the entire area in great level beyond the recommended tolerant limits. According to Adeagbo (2011), the issue of the Exide battery indiscriminate waste dumping was not restricted to a particular location but there were several places in Olodo with traces of battery wastes and Alloway (2004) stated that heavy metal concentrations in agricultural soils are generating public concern globally because these heavy metals are gradually dispersed into the different parts of the environment and thus, bio-accumulate as well as bio-magnify in food chains.

5.1.2 Cadmium

Cadmium ranks number seven in the list of the 'top twenty hazardous substance (Roberts, 1999). It is commonly used in batteries, with other sources of exposure being automobiles exhausts among others. When toxicity and exposure occurs, target organs for injuries include liver, kidneys, bones, lungs, placenta and brain (Roberts, 1999). Therefore, this implies that cadmium is also a major component of battery wastes.

This study has revealed that cadmium concentration in the topsoil of the waste dumpsite and those of distances 0 m - 25 m along the gradient point directions North, South, East and West from the edge of the waste dumpsite were significantly higher than the values obtained from the control topsoil. The cadmium concentrations obtained were also several folds higher than the maximum permissible limit of 50 mg/kg by NESREA (2011). According to WHO (1992), the median cadmium concentration in soil of areas not known to be polluted has been reported to be in the range of 0.2 - 0.4 mg/kg; though much higher values are occasionally found, up to 160 mg/kg soil (WHO, 1992). The cadmium concentrations obtained in this study were far higher than these stated values.

Cadmium levels obtained in this study were also much higher than the values given for natural soil cadmium concentration given by Olade (1987). According to Olade (1987), cadmium level ranges from 0.2 - 0.8 mg/kg and 2.0 - 12.0 mg/kg in tropical soils, depending on the nature of the underlying bedrock with the mean of either 0.35 mg/kg or 4.50 mg/kg. Similarly, the values obtained for soil cadmium in this study

were several folds beyond the background concentration of 0.01 - 0.2 mg/kg given by Ahmed and Suleiman (2001) in soil samples studied in the evaluation of groundwater and soil pollution in a landfill area using electrical resistivity imaging survey.

The mean cadmium concentration obtained in this study, when compared to the other studies carried out in Olodo environment showed that they were higher than the mean cadmium level of 1.95 - 32.83 mg/kg obtained by Oyediran and Aladejana (2011) in their studies on battery waste polluted areas. These results were also higher than the mean cadmium level obtained by Adie and Osibanjo (2009) in their study on soil polluted by slag from an automobile battery manufacturing plant in Nigeria.

The concentration of cadmium in this study was compared to those found in several other studies conducted on top soils in Nigeria. The cadmium level in this study were higher than the mean cadmium level of 0.01 mg/kg - 0.35 mg/kg in soils of Ota metropolis, Ogun State, Nigeria obtained by Olukanmi and Adebiyi (2012); of 2.9 mg/kg in soil around Ikeja industrial estate, Lagos by Fakayode and Onianwa (2002); 0.92, 1.01 and 1.07 mg/kg in soil samples from upstream and downstream soils as well as those within the landfill soil samples studied in the evaluation of groundwater and soil pollution in a landfill area using electrical resistivity imaging survey by Ahmed and Suleiman (2001); 22 - 66 mg/kg in agricultural soils located near a solid waste dumpsite in Gaza Strip obtained by Shomar *et al* (2005); 0.06 - 4.90 µg/g (mg/kg) in the studies of soil quality around a solid waste dumpsite in Port-Harcourt, Nigeria by Ideriah *et al* (2006); 17.22 - 34.81 mg/kg in Waste Dumpsite Area topsoil samples as well as 0 - 4.31 mg/kg in Leachate Lagoon Area topsoil samples studied by Oni (2010) in Aba-Eku landfill site, Ibadan, Nigeria and 0.41 - 17.23 mg/kg obtained for cadmium concentration in topsoil of automobile mechanic villages in Ibadan, Nigeria studied by Adelekan and Abegunde (2011).

In all of the gradient points sampled around the waste dumpsite, it was realized that the cadmium concentrations for distance 0 m towards the North and West were slightly higher than the values obtained in the waste dumpsite while all the other sampled distances along the gradient points had a little less than the value obtained in the waste dumpsite. This may be due to the fact that distance 0m along the gradient points is the beginning of the rectangular waste dumpsite fringes and as such, the battery wastes could have been directly deposited there as well. Also, the source could probably be

associated with Galena (PbS) alloy in battery since cadmium is often an impurity in the alloy (Holmes, 1976; Adriano, 1986; Adie and Osibanjo, 2009).

The improper disposal of battery wastes on soil, like the case of Ori-Ile waste dumpsite, could cause soil pollution in the community and this could initiate exposure of residents to toxic cadmium level, which could lead to several health hazards for the residents.

5.1.3 Iron

The toxicity of iron is not common because it is an essential nutrient element needed by green plants, animals and humans for their well-being (Anikwe and Nwobodo, 2002). However, iron toxicity can result from excessive exposure, which can be cumulative when originating from many sources (Roberts, 1999). The high iron concentration obtained in this study is most likely cumulative with those originating from the natural soil level in Ori-Ile environment contributing to the high concentration obtained rather than just the disposed wastes.

This study has revealed that iron concentration in the topsoil of the waste dumpsite and those of distances 0 m - 25 m along the gradient point directions North, South, East and West from the edge of the waste dumpsite were significantly higher than the values obtained from control topsoil. According to Eddy *et al* (2006), the background level of iron in natural soils was stated to range widely between 3,000 - 500,000 mg/kg on elemental composition of soil in some dumpsites in Nigeria. The values obtained for soil iron concentrations in this study compares with the range reported by Eddy *et al* (2006) as the background level of iron in natural soils.

The values obtained for soil iron level in this study were higher than the range of 423 mg/kg - 437 mg/kg obtained by Anikwe and Nwobodo (2002) but very much less than the range of 69,140 mg/kg - 83,241 mg/kg obtained in the studies of Eddy *et al* (2006) and the range of 14821.87 - 69641.05 mg/kg in Waste Dump Area topsoil samples as well as 18129.17 - 62223.25 mg/kg in Leachate Lagoon Area topsoil samples studied by Oni (2010). Furthermore, these concentrations of iron obtained in this study, when compared to the other studies carried out at Olodo environment, revealed that they were several folds lower than the range of 32900.08 mg/kg - 71250.17 mg/kg obtained by Oyediran and Aladejana (2011).

In all of points sampled around the waste dumpsite, it can be observed that distance 10 m towards the East, South and North had slightly higher iron concentrations than the value obtained on the waste dumpsite while all the other sampled distances along the gradient points were less than the value obtained on the waste dumpsite.

5.1.4 Inter-relationship between Analyzed Heavy Metals in Soils

The result of the determination of the correlation coefficient of the values obtained for lead, cadmium and iron in the topsoil samples of the waste dumpsite and those of distance 0 m - 25 m along the gradient points directions around the waste dumpsite indicated that there was a significant inter-correlation at confidence limit p=0.05 (Appendix 5). Oni (2010), Rieuwerts *et al* (2006) and Navas and Machin (2002) stated that most soil elements showed significant inter-correlations. The findings of this study agree with this statement.

For all of the period of sampling, there was a significant positive inter-correlation between lead and cadmium and between lead and iron at p=0.05, each of which were above 0.6 respectively. Also, there was a significant positive inter-correlation which were above 0.6, between cadmium and each of lead and iron at p=0.05. Iron also showed positive and significant inter-correlation with lead and cadmium respectively (Appendix 5).

Therefore, there suggests that the increase in concentration of any one of the metals will cause a corresponding increase in the concentration of the other two. Also, it implies that the presence of the three metals in super-abundant concentration indicated that the wastes discarded on the waste dumpsite consisted of the three analyzed heavy metals in an inter-relational measure such that the presence of higher concentration of lead could also be the reason why cadmium and iron were found in considerable high concentrations as well. As such, these three metals are somehow part of the components of the battery waste.

5.1.5 Contamination Factors and Pollution Load Indices of the Topsoil Samples from Ori-Ile Waste dumpsite and Surrounding Gradient Points

According to Agunbiade and Fawale (2009), contamination factor and pollution load index are accumulative factors, which are calculated for the metals in soils and used as

basis for interpreting the state of the environment. The calculation of the contamination factor (CF) and pollution load index of the topsoil from the random waste dumpsite and those along the gradient points in this study gives a clearer picture of the trend of the level of contamination of the studied heavy metals in the soil. The contamination factor (CF) has been used to assess soil contamination (Hakanson, 1980) through comparison of the concentrations in the surface layer to background values (Agunbiade and Fawale, 2009). According to the study of Shakeri *et al* (2009), lead revealed considerable contamination in soils of Shiraz industrial complex zone. Agunbiade and Fawale (2009) also found that lead and cadmium accumulative factors in the soil were less than that of the plant.

All soil contamination factors and pollution load indices were significantly high (CF>6; PLI>1). This confirmed high pollution of the waste dumpsite and its surrounding gradient point areas. From the contamination factor and pollution load index values obtained, cadmium was the highest contaminant in all the top-soils sampled at the study site, followed by lead and iron. The CF and PLI values for samples collected from the random waste dumpsite for lead indicated that the topsoil on the waste dumpsite had the highest pollution followed by the topsoil of North, West, East and South in that order.

Similarly, the CF and PLI values for random waste dumpsite samples for cadmium indicated that the topsoil on the waste dumpsite had the highest pollution followed by the topsoil of West, North, East and South in that order. The CF and PLI values for random waste dumpsite samples for iron indicated that the topsoil on the waste dumpsite also had the highest pollution followed by the topsoil of East, North, South and West in that order.

The contamination of the soil with iron is not much of a concern if not ingested, since iron is among the required beneficial metals to plants and animals, though absorption of very high concentration without immediate utilization in the body could lead to toxicity. However, cadmium and lead are of serious concern and adequate control of their sources is paramount because of their negative impact on biota and the ecosystem at large. Lead and cadmium affect metallothionein, a cystine rich, low-molecular weight, metal-binding protein (Perceval *et al*, 2002) and hormonal activity in living organisms (Laflamme *et al*, 2000). Lead has caused anaemia, brain damage, anorexia,

renal failure, mental deficiency, vomiting and even death in human (Bulut and Baysal, 2006; Low *et al,* 2001) even at trace levels lower than the observed concentration in this study. Cadmium also has been reported to cause bone disease, agonistic and antagonistic effects on hormones and enzymes leading to lots of malformations (Manahan, 1992). Renal damage resulting in proteinuria has been caused by cadmium through its adverse effect on the enzyme responsible for the re-adsorption of protein in the kidney tubules (Donalson, 1980). These two metals have affinity for sulfhydryl groups in proteins, haemoglobin, enzymes/hormones thus affecting their activities (Manahan, 1992).

5.2 Physical and Chemical Parameter of the Soil Samples

5.2.1 Soil pH

The mean pH values obtained for the topsoil of the waste dumpsite and the surrounding gradient points were mainly acidic based on the classification of ASTM (1995). The pH value obtained for soil samples from the waste dumpsite and those of distance 0 m - 25 m along the gradient points were acidic and not significantly different from each other while the mean values obtained for the topsoil of the control were within the range classified as neutral.

The range of pH values obtained from this study was similar with those of 5.0 - 7.4 obtained by Anikwe and Nwobodo (2002); 4.22 - 7.93 obtained by Adie and Osibanjo (2009) and 5.1 - 9.4 obtained by Ideriah *et al* (2006). However, the mean soil pH values obtained in the study site were less than 7.02 - 8.65 and 6.59 - 7.51 obtained for waste dumpsite area and leachate lagoon area studied by Oni (2010). They were also less than pH value of 7.5 obtained in the study of Ahmed and Suleiman (2001). This further indicates that the soil pH of the Ori-Ile dumpsite area were majorly acidic compared to the above studies.

The pH results obtained in this study may be as a result of the acidic components of the battery production, which were contained in the waste. Hence, when the battery wastes were disposed on the soils, they modified the soil's pH, causing it to be more acidic. This can affect the uptake and bio-accumulation of the toxic components of the battery wastes. McKim and Erickson (1991) in their study on environmental impacts on the physiological mechanisms controlling xenobiotic transfer across fish gills stated

that pH and salinity can affect Transfer. The uptake of cadmium by plants from soil is also greater at low soil pH (WHO, 1992). The pH of the topsoil of the study site being acidic fit into the above statement and could enhance the uptake of lead and cadmium into plants growing on the polluted dumpsite environment. Similarly, Overcash and Pal (1979) stated that the absorption of metals may be promoted by pH in the acid range and in the presence of organic complex-forming agents for which heavy metals are solubilized to a greater extent in soil solution.

Apart from this, the waste dumpsite is different from the municipal waste dumpsites in that it does not have different waste components from numerous sources. As such, the Ori-Ile battery waste dumpsite could not have an interaction of the different waste materials within the disposed battery wastes as opposed to what obtained in the control topsoil. The soil pH property could only have being influenced mainly by the acidic property of the components of the battery wastes.

5.2.2 Soil Organic Matter

Soil organic matter is the organic fraction of the soil that is made up of decomposed plant and animal materials as well as microbial organisms, but does not include fresh and un-decomposed plant materials, such as straw and litter, lying on the soil surface (Yin, 2008). Enwezor *et al* (1988) gave the critical limits for soil organic matter. The organic matter levels that are less than 2.0 % are considered low while 2.1 - 3.0 % are classified as medium and those greater than 3.1 % are grouped as high (Enwezor *et al*, 1988). The mean organic matter obtained in this study for soil of the study site is much less than that of the control site. The mean organic matter content obtained for soil of the waste dumpsite were less than 2 % and as such, have low soil organic matter while that of soil taken from the gradient points were greater than 2 % but less than 3 % and as such, have medium organic matter content. The soil organic matter content of the control was high being greater than 3.1 %.

The range of organic matter obtained in this study from Ori Ile waste dumpsite were much less than the range of 4.53 % - 11.69 % obtained by Oni (2010) for the waste dumpsite area top soils though they were within the range of 1.14 % - 2.41 % obtained for the top soil samples of leachate lagoon area in the same study. Furthermore, the range obtained in this study was much less than 15.3 % - 22.01 % obtained by Anikwe

and Nwobodo (2002) though it compares with the range of 1.43 % - 6.76 % reported by Ideriah *et al* (2006).

The observation of the inability of the soil of the waste dumpsite to support much vegetation contributes to its low soil organic matter content. There was a gradual increase in organic content of the soil as the sampling distance moves away from the waste dumpsite, due to gradual introduction of other household wastes to the soil. Apart from this, the availability of much vegetation in the surrounding gradient points contributes living and dead decomposing materials to the soil, thereby increasing its organic matter. As such, there was increase in the amount of decomposable materials that add to soil organic matter (Ideriah *et al*, 2006).

According to Anikwe and Nwobodo (2002), increased organic matter content may lead to increased soil productivity. The low soil organic matter content on the waste dumpsite could also be attributed to the lack of other types of waste on the waste dumpsite except for the battery wastes. These battery wastes do not have decomposable materials. Hence, the soils on the waste dumpsite may be poor in productivity due to its low soil organic matter. However, the medium characteristic of the surrounding soil organic matter may be an added advantage for residents since the soil could support agricultural activities.

5.2.3 Soil Organic Carbon

Soil organic carbon is the carbon associated with soil organic matter (Yin, 2008). The soil organic carbon contains humus materials with highly complex functional groups, which have ability to complex metals thereby retaining them in the topsoil (Evans, 1989). Soil organic carbon accounts for less than 5 % on the average of the mass of the upper soil layers, and diminishes with depth. In good soils, soil organic carbon can be greater than 10%, while in poorer or heavily exploited soils, levels are likely to be less than 1 % (Young Carbon Farmers, 2015).

According to the Department of Agriculture and Food, Western Australia (2015), about 58% of the mass of organic matter exists as carbon. This implies that if the organic matter content of the soil is low, it will affect the percentage organic carbon such soil contains. Soil organic carbon is the main source of energy for soil micro-organisms. The ease and speed with which soil organic carbon becomes available is

related to the soil organic matter fraction in which it resides. Also, the more organic carbon is present in soil, the more the functional groups available for complex formation with the metals, hence, the more the retention of the metals.

The mean values obtained for soil organic carbon in this study was less than those obtained for the control soil but within the range of 0.27– 3.33 % obtained in the study of Adie and Osibanjo (2009) in their study of similar soil polluted with battery waste in Nigeria. Also, the mean soil organic carbon was less than 3.41 % and 2.90% obtained by Ogbona *et al* (2009) in their study of some physico-chemical parameters and heavy metal levels in soils of waste dumpsites in Port Harcourt municipality and environs and they attributed this values to the utilization of the elements by micro-organisms as sources of nutrients and mineralization process.The soil organic carbon content of Ori Ile site is a little above 1 % but less than 10%, which showed that it was poor and the soil had low productivity. This low soil organic carbon content of the soil is further confirmed by the level of the non-productivity of the waste dumpsite and its inability to support effectively both flora and fauna within the soil; especially due to the high level of contamination of the soil. There is need to increase the organic carbon content of the soil of Ori-Ile study site for the reason that if more carbon is stored in the soil through the process of soil carbon sequestration, it will reduce the quantity present in the atmosphere and as such, help in reducing global warming.

5.2.4 Cations Exchange Capacity

Cation exchange capacity is often least for sandy soils and most for clayey soils. Cation exchange capacity is a key chemical characteristic of soils and an important measure of soils' fertility. It is a calculated value that is an estimate of the soils ability to attract, retain and exchange cation elements. The values obtained for cation exchange capacity of soil samples in this study were much higher than those obtained from the control soil. The values obtained for soil cation exchange capacity in this study were close to the range of 160.0 - 280.0 cmol/kg obtained by Asadu *et al* (1997). They also compares well with the range of 114.0 - 264.0 cmol/kg reported by Oorts *et al* (2003) and 111.0 - 693 cmol/kg obtained by Meyer *et al* (1994). The results were high when compared with the standard value classification of 40 meq/100g by Tel and Hargarty (1984). However, the values obtained in this study were less than the range of

294.9 - 521.1 cmol/kg obtained by Oni (2010) in the top soils of the waste dumpsite area of Aba-Eku landfill site, Ibadan, Nigeria.

In addition, the cation exchange capacity of soil samples in this study was much higher than 51.4 - 92.1 cmol/kg obtained by Oni (2010) in the top soils of the leachate lagoon area of Aba-Eku landfill site, Ibadan, Nigeria and 11.90 - 14.58 cmol/kg obtained by Ahmed and Suleiman (2001). The range of values obtained in this study was also much higher than 3.50 - 46.0 meq/100g obtained by Ideriah *et al* (2006) and 44.0 - 120 cmol/kg obtained by Al-Khashman and Shawahbkeh (2006). Larger cation exchange capacity values indicate that a soil has a greater capacity to hold cations and ought to have high nutrient. The cations in polluted soil could be the positively charged heavy metals instead of the required cationic nutrients.

These high cation exchange capacity values may be due to the high heavy metal concentrations within the topsoil as a result of the battery wastes that were disposed on it. Hence, the cation exchange capacity of the soils of the study site help in explaining its retention of the three heavy metals i.e. lead, cadmium and iron that were discovered in very high concentrations within the soil. These three metals being cations were attracted to the topsoil of the study site which is sandy clayey type with enormous negatively charged ions. The chemical reactions in cation exchange make it possible for calcium and the other required elements to be changed into water-soluble forms that plants can use for food but this could be detrimental if toxic heavy metals like lead and cadmium replace the essential cations such as calcium and become absorbed into plants.

5.2.5 Soil Particles Size Distribution

The values obtained for soil particles size distribution in this study showed that the top soil on the waste dumpsite was predominantly sandy and has significantly reduced amount of silt and clay. The distribution of soil particles along the gradient points around the waste dumpsite also showed higher percentage sand particles composition with a reduced silt and clay content. Soil particles describe soil's texture, which is the relative percentage of each particle size within a soil depending on the proportion of sand, silt, and clay. Texture is important in measuring soil productivity. As a result, texture differences can affect many other physical and chemical properties (King,

2009). A soil combination of 10 - 20% clay, along with sand and silt in roughly equal amounts, and a good quantity of organic materials, is considered an ideal mixture for productive soil (King, 2009).

Oni (2010) reported a high percentage of sand of 50.33 - 59.79% in the soils of the waste dumpsite with very little amounts of silt and clay of 2.66 - 7.96 %. Similarly, studies by Benka-Coker and Bafor (1999) on the soils of the Teboga waste dumpsite in Benin City, Nigeria revealed that the soils were predominantly sandy while Anikwe and Nwobodo (2002) in their studies of Abakaliki dump site had high percentages of sand and the authors concluded that soils with sand content greater than 70% were not suitable for waste disposal because of their high permeability which will allow the leachate to pass through the soil.

The percentage sand found in the waste dumpsite and the surrounding gradient point directions were higher than those recorded by Oni (2010) at Aba-Eku landfill site, Ibadan, Nigeria and also exceeded the 70 % stipulated minimum for soils designed for waste disposal according to Anikwe and Nwobodo (2002).

Hence, the soils of the waste dumpsite and its surrounding environment have predominantly sand particles which according to King (2009), is not suitable for waste disposal in that the soil particles tend to drain quickly making the soil have lower fertility. Therefore, the toxic components of the waste discarded on this soil type could be easily distributed into the surrounding part of the community through erosion especially into the water sources. It could serve as a means by which the toxic components of the battery wastes could be leached into the underground layers and especially into the underground aquifer. Likewise, this soil type has no discernible structure and is not well-suited for agriculture.

5.2.6 Soil Permeability

The part of the soil that is not solid is made up of pores of various sizes and shapes. Soil scientists refer to the size, number, and arrangement of these pores as the soil's permeability. Permeability greatly affects water movement and gas exchange. Well-aggregated soils have numerous pores, which are important for organisms that live in the soil and require water and oxygen to survive. The transport of nutrients and contaminants will also be affected by soil structure and permeability (King, 2009).

From the result obtained for the soil permeability in this study, it was observed that there was no difference in the permeability pattern of all the soil samples of the study site though these were significantly higher than the control soils. According to Diaz and Savage (2002), the stipulated minimum for soil permeability in landfill soils is 1 x 10^{-6} cm/sec. Oni (2010) obtained a permeability range of 5.2 x 10^{-5} - 1.69 x 10^{-4} cm/sec for the waste dumpsite while that of the leachate lagoon area was a range of 7.6 x 10^{-5} - 1.95 x 10^{-4} cm/sec. Benka-Coker and Bafor (1999) obtained a mean permeability range of 8.03 x 10^{-3} - 1.75 x 10^{-4} cm/sec while Anikwe and Nwobodo (2002) obtained a range of 4.5 x 10^{-3} - 5.1 x 10^{-3} cm/sec. The results of the permeability of the topsoil of the waste dumpsite and its immediate surrounding gradient points are very high compared to that of Oni (2010), Diaz and Savage (2002), Benka-Coker and Bafor (1999) as well as Anikwe and Nwobodo (2002).

Hence, the high permeability results obtained in the waste dumpsite and its surrounding soil samples indicated that the waste components will be leached rapidly through the soil, thus contaminating the underlying groundwater. This is further confirmed by the results obtained for the particle size distribution which have higher percentage of sand and less percentage silt and clay, thus confirming the soil being highly inappropriate for dumping of wastes.

5.2.7 Soil Mineral Content and Percentage Base Saturation

The earth's soil holds 13 different minerals that provide nutrients to plants. It is not all of these essential minerals that are present in every type of soil. The results obtained for soil mineral content in this study showed that only the mineral content of the soil samples from the South gradient point was slightly higher than that from the waste dumpsite. These slightly high results from the south could be related to the reduced level of pollution as indicated by the heavy metal content of the soil of that area compared to the waste dumpsite (Figure 4.20). However, the other gradient points showed less mineral content compared to the waste dumpsite and this is an indication of a higher level of contamination of the soil in that area. The sandy-clayey nature of the soil particles of the dumpsite and its surrounding gradient points, with high percentage sand could be responsible for the less mineral content of the soil of the study sites except the south gradient point. The high soil mineral content of the south gradient point could also be as a result of its position which is at the receiving part of

the slope on which the dumpsite is situated. Although the high adsorbing capacity of lead to soil prevents it from being easily leached down by rain water towards the south gradient direction, which makes it impossible for the south to have the highest level of the three studied metals. However, it is possible for the soil at the southern gradient point to receive all the mineral content from the other parts but could also be susceptible to receiving leachable toxic components as well. By nature, sand particles do not hold on to many minerals and nutrients required by plants for their well-being. Although, sandy soils are often considered poor for plant growth, but if mixed with other soil types in the appropriate ratio, they could serve to enrich plant growth. This is because of the large amount of nitrogen, phosphorus and potassium contained in them. The only disadvantage of a highly sandy soil type is the fact that it is loose and quick draining and as such, could allow the soil nutrient and other metallic content to be easily leached away. The low soil mineral content could also be attributed to the low soil organic matter and organic carbon, which was as a result of less vegetation on the dumpsite and its surroundings compared to the control site.

The values obtained for soil percentage base saturation of the study site were less than the value obtained for the control soil. The percentage base saturation is a measurement of the percentage of the soil cation exchange capacity that is occupied by the sum of a group of nutrients. It is used in predicting the soils ability to provide adequate crop nutrients. 100 % base saturation is the combined percent saturation of the three major cations that have an alkaline reaction namely K^{+}, Ca^{++} and Mg^{++}. These three metals are replaceable with either or both of Pb^{++} and Cd^{++} due to the super-abundance of the heavy metal in the topsoil of the study site as a result of the disposed battery waste. This was why the percentage base saturation obtained was high. Likewise, the low pH obtained in the study site made the cation saturation to be less than 100% as a result of the bound-cations in the acidic topsoil of the study site that was not extracted in the soil testing process.

5.3 Lead, Cadmium and Iron Concentrations in the Water Samples around Waste Dumpsite

5.3.1 Lead, Cadmium and Iron Concentrations in the Groundwater Samples around Waste Dumpsite

5.3.1.1 Lead

Lead was found in significant amount in the groundwater located in all the gradient points around the waste dumpsite but the concentration found in the East groundwater was the highest. The concentrations of lead found in the water samples were higher than NESREA standard regulatory limits except for those in the south well. Also, the concentrations of lead found in the water samples fall within the range of 0.000 - 0.145 mg/l obtained for groundwater in the study of Oni (2010).

The high level of lead in soil could lead to high concentration of lead being leached down the soil profile into the underground aquifer. According to Prasad and Freitas (2000), lead salts have low solubility and as a result of this, it tends to precipitate out of complex solutions. There is the tendency for some level of mobility of the metals in the waste dumpsite soil into the underlying aquifer since the concentration of lead in the soil samples is very high. It was observed that lead concentration in the East soil was very high and the East groundwater also had high lead content. Oni (2010) observed a similar trend in the groundwater samples of Aba-Eku. All this agrees with the observation of Oni (2010) that elevated levels of metals in the groundwater wells she studied suggested some degree of mobility of the metals in the landfill soils which ultimately impacted the groundwater. Although soil retards the movement of lead through terrestrial communities, some lead may be leached from highly contaminated soils (WHO, 1995).

In a similar study on the impact of waste batteries dumpsites on the water quality of parts of Ibadan North-East by Adeagbo (2011); he observed that the concentration of lead found in the groundwater at Olodo, Ikumapaiyi and Arubiewe exceeded the maximum permissible level. He inferred that the leachate from the waste batteries dumpsites, which came in contact with shallow groundwater, was responsible for the high values of Pb, Cd and Cu. This could also be the case in this study.

The results of lead concentrations obtained for groundwater in this study was more than those obtained for lead concentration in topsoil studied at automobile mechanic villages in Ibadan, Nigeria by Adelekan and Abegunde (2011). Lead is a heavy metal of great environmental concern and poses threat to plants, animal and human health due to its bio-accumulative tendency and toxicity (Horsfall and Spiff, 2004). According to Rajaratnam *et al* (2002), lead can be toxic at very low concentrations and a continued exposure to lead in the environment can pose serious health hazard (Environmental Compliance for Automotive Recyclers, 2005).

Despite the fact that water is an indispensable necessity of life, it can serve as one of the major entry routes through which toxic elements like lead enters into the human body system. According to WHO (1995), exposure to lead remains an important cause of disease. Gradual consumption of water polluted with lead can cause chronic toxicity over time due to the accumulation of the heavy metal in vital organs of the body of its consumer. Thus, the concentration of the metal that looks inconsequential and negligible could cause fatal health effects if ignored. Ignorance of the risks of lead contamination and a lack of viable economic alternatives such as good water supply, has led to the systemic poisoning of many poor populations throughout the developing countries (Blacksmith Institute, 2011), with varying degree of health effects on different human gender and ages.

Therefore, if no remediation measure is carried out soon, there is possibility of cases of chronic poisoning from the continual use of these ground waters as sources of drinking water.

5.3.1.2 Cadmium

The results obtained from the well water samples from the gradient points around the waste dumpsite in this study showed that all the wells in the gradient points have cadmium concentrations that are higher than the control site and NESREA standard, except for the well located along the South gradient point. Cadmium is a very toxic heavy metal and its presence in any drinking water poses significant level of health risk due to the various effects that can be elicited as a result of its consumption. Drinking-water generally contains low cadmium levels and a value of 1 µg/l or less is often assumed to be a representative value in most situations (Meranger *et al*, 1981).

Cadmium intake from drinking-water based on a daily consumption of 2 liters is usually less than 1 µg (WHO, 1992).

All the values obtained for cadmium concentration in groundwater in this study were several folds less than those obtained by Oni (2010), who attributed the high cadmium concentrations of the studied groundwater to the high leach-ability and mobility status of the metal. According to WHO (1992), the disposal of wastes containing cadmium is one of the major sources of contamination to land and water resources. Christensen *et al* (1996), Kugler *et al* (2002), Sahuquillo *et al* (2003) and Essaku *et al* (2005) all agrees to the fact that cadmium can be easily leached within the soil and related this property to the metal's high mobility status. Therefore, the relatively high cadmium content of the ground waters studied can be said to be corroborated by these observations.

The result of the study by Adeagbo (2011) showed that the concentration of cadmium found in the groundwater exceeded the maximum permissible level in Olodo. Adeagbo (2011) also attributed the high cadmium concentrations in the groundwater to be due to the leachate from the waste batteries dumpsites, which came in contact with shallow groundwater. The results obtained for cadmium concentration in groundwater in this study was also more than those obtained for cadmium concentration by Adelekan and Abegunde (2011). Hence, cadmium concentrations in the groundwater of Ori Ile Olodo environment can be said to be higher than the WHO maximum limit in drinking water.

The mobility of cadmium in the environment and the effects on the ecosystem depend to a large extent on the nature of its compounds (WHO, 1992). Some of the cadmium salts, such as the sulfide, carbonate or oxide, are practically insoluble in water. However, these can be converted to water-soluble salts in nature under the influence of oxygen and acids. Acidification of soils may result in enhanced mobilization of cadmium thus leading to increased levels in surface and ground waters (WHO, 1987). This implies that the acidic nature of the soil of Ori-Ile study site and its surrounding environment along the gradient points could have influenced the solubility of cadmium and converted it into water soluble salts, which made it accessible to consumers of such groundwater. As a result, the sulfate, nitrate, and halogenates of cadmium are soluble in water. This speciation of cadmium in groundwater and surface water is important for the evaluation of its potential hazard (WHO, 1992).

Due to the fact that the intake of cadmium from water is related to both the extent of contamination and the reliance on local water supplies such as groundwater (WHO, 1992); the concentration in this study can be a significant source of exposure and threat to the residents' health when they continually consume the contaminated ground waters. According to Andreani *et al* (2008), cadmium has been found to have no known useful function in biological organisms. Chofqi *et al* (2004) and Hsu *et al* (2006) stated that cadmium has neuro-toxic effects and has the potential to bio-concentrate in living tissues. Chaudri *et al* (2001) stated that exposure to cadmium is of particular concern due to the chronic health problems that it causes. Thus, cadmium exposure from the consumption of these contaminated Ori-Ile ground waters could result in gradual cadmium toxicity arising from its bio-accumulation and these could result in effects such as anemia, liver damage, renal dysfunction etc., if no preventive measure is put in place.

5.3.1.3 Iron

The values for iron concentration obtained in the groundwater of this study were more than the values obtained from the control groundwater but less than NESREA standard. According to Dahi (1991), iron concentrations below 0.3 mg/l in well-water were characterized as unnoticeable, whereas levels in the range of 0.3–3 mg/l were found acceptable. The average lethal dose of iron is 200–250 mg/kg of body weight, but death has occurred following the ingestion of doses as low as 40 mg/kg of body weight (NRC, 1979).

As a precaution against storage of excessive iron in the body, JECFA (1983) established a provisional maximum tolerable daily intake (PMTDI) in 1983 of 0.8 mg/kg of body weight, which applies to iron from all sources except for iron oxides used as colouring agents, and iron supplements taken during pregnancy and lactation or for specific clinical requirements (WHO, 2003). Allocation of 10% of this PMTDI to drinking-water gives a value of about 2 mg/l, which does not present a hazard to health. The taste and appearance of drinking water will usually be affected below this level, although iron concentrations of 1–3 mg/l can be acceptable for people drinking anaerobic well-water. All the mean groundwater iron concentrations obtained in this study were less than the values given above.

Iron is part of the trace element that is vital for the healthy functioning of a living human body. Naturally, water contains minute quantities of iron (Redmond, 2008). But, apart from natural sources, iron is also among the more common metals that find its way into groundwater. Iron oxides and salts found in soil may work their way into a groundwater supply with no obvious signs, depending on the concentration (WHO, 2003). Furthermore, iron presence in water could cause water hardness and also give rise to an unpleasant taste in drinking water (Lee and Jones-Lee, 1999; Redmond, 2008). Individuals who consume water contaminated with iron for a prolonged period may develop iron toxicity, a potentially deadly condition (WHO, 2003).

The groundwater iron concentrations obtained in this study were less than those obtained by Oni (2010). According to Mor *et al* (2006), groundwater with moderately high concentration of iron among others most likely indicates that its quality is being significantly affected by leachate percolation. Marzougui and Mammou (2006) also observed high amounts of heavy metals and organic pollutants in groundwater surrounding the Henchir El Yahoudia dump site. Pujari and Deshpande (2005) studied the source apportionment of groundwater pollution around a landfill site in Nagpur, India, they revealed significant contribution of iron and aluminum in the groundwater close to the landfill site and at a lower elevation. The result in this study also indicated a similar trend in iron availability in the well water though the concentrations found were lower.

Although, the concentration of iron found in the groundwater of this study could have being as a result of the high concentration found in the soil, it is relatively low to cause any significant harm. Furthermore, the human body has the means of getting rid of excessive iron intake when its concentration is not excessively much (DNHW Canada, 1990). Staining of laundry and plumbing may occur at iron concentrations above 0.3 mg/l (DNHW Canada, 1990).

Hence, iron concentration in Ikumapaiyi well waters does not constitute a means of toxicity to residents of the Ikumapaiyi community and their domestic animals as a result of the continual usage and consumption of the well waters.

5.3.2 Lead, Cadmium and Iron Concentrations in the Omi Stream Water Samples of Ori-Ile Waste dumpsite Area

The results of the concentration of lead and cadmium in Omi stream water studied showed that downstream had the highest followed by the midstream. However, lead and cadmium were not detected in the upstream location of the study and the control sites. The value obtained for the concentration of lead and cadmium in the downstream was very much higher than the NESREA standard but those in the midstream were less than NESREA standard. This result is in agreement with the observation of Adeagbo (2011) that the concentration of lead and cadmium exceeded the maximum permissible level in surface waters of Olodo, Ikumapaiyi and Arubiewe. The Leachate from the waste batteries and accumulators' dumpsites that came in contact with surface water was considered to be responsible for the high values of the metals. The location of the midstream at the base of the waste dumpsite and the downstream away from the dumpsite following the direction of the water flow makes the pattern observed in the results of this study similar to what Adeagbo (2010) obtained.

One of the greatest problems of water supply and usage especially in the developing areas such as Ori-Ile Olodo, is the condition of the water. Often times, water runoff, a nonpoint source of pollution, carry toxic pollutants from land areas into streams and rivers, thus causing serious aquatic pollution. Similarly, according to WHO (2007), contamination of drinking water is a significant concern for public health throughout the world because chemicals in water supplies can cause serious health problems, whether the chemicals are naturally occurring or derive from sources of pollution. Thus, lead and cadmium, along with other heavy metals in the wastes were eroded from the topsoil by rain water and was deposited into the stream. This is of considerable health and environmental concern because of their toxicity and bio-accumulative behaviour (Omgbu and Kokogbo, 1993; Ajibola and Ozigis, 2005; Nsikak, 2006).

According to Blacksmith Institute (2011), this polluted source of water supplies when used for domestic and agricultural purposes could serve as route through which these toxic metals enter into the food chain. Similarly, the contamination of fresh water systems could cause adverse effects on aquatic biota and human health (Wang, 2002; Dautremepuits *et al*, 2004). Heavy metals cannot be destroyed through biological

degradation and they have the ability to accumulate in the environment (Nsikak, 2006). Hence, lead and cadmium in this study are deleterious to the aquatic environment and constitute harm to humans who depend on the Omi stream water for sustenance.

Naturally, water contains minute quantities of iron (Redmond, 2008). But, apart from natural sources, iron also finds its way into surface waters. The median iron concentration in rivers has been reported to be 0.7 mg/liter by WHO (2003). Rivers contain approximately 0.5-1 ppm of iron (Plieth, 2007). Presence of iron in water could cause water hardness and also give rise to an unpleasant taste in drinking water (Lee and Jones-Lee, 1999).

All the results obtained for iron concentration in this study were less than the WHO and NESREA standards. The downstream had the highest iron concentration and this was followed by midstream and upstream. Oyediran and Aladejana (2011) obtained a range of 0.30 – 2.84 mg/l for iron in their study of Olodo water. Results from the present study showed a similar trend.

The toxicity of iron is governed by absorption (Muhsin *et al*, 2010). If aquatic organisms take in over-abundant concentration of iron into their system, it could lead to its accumulation within the body of those organisms, which when consumed, will contribute to iron body burden of the consumer be it animal or human and thus result in iron toxicity (Muhsin *et al*, 2010). However, iron in the stream water of the study site was in lower concentration. The general population may get exposed to lead and cadmium, through the consumption of the contaminated Omi stream water and this could result in acute toxicity over time through the process of bio-accumulation. Additionally, the exposure of Ori-Ile residents could occur through the consumption of food grown in gardens that were irrigated with the polluted Omi stream water and this may eventually lead to serious health challenges in these residents.

5.4 Cultivated Maize Samples

5.4.1 Lead, Cadmium and Iron Concentrations in the Cultivated Maize Samples

Plants have evolved detoxification mechanisms (Clemens, 2001) and the efficiency of these processes might result in the tolerance of the natural heavy metals (Salt *et al*, 1995). Cereals such as maize are known to be good accumulators of contaminants

(Malgorzata and Andzej, 2005; Aliu *et al*, 2013). Many researchers have investigated the uptake and accumulation of lead and cadmium in different plant species (Clemens, 2001; Malgorzata and Andzej, 2005; Aliu *et al*, 2013). Infact, the uptake, metabolism and negative effects of heavy metals on maize have been documented in literature (Aliu *et al*, 2013). However, the mechanism of accumulation of these metals is still not completely understood (Malkowski *et al*, 2005). Lead and cadmium are the most widespread no-nutrient heavy metals (Mihailovic, 2010).

Results obtained in this study showed high concentrations of lead, cadmium and iron in the roots, stems, leaves and grains of maize plants when compared with levels in the same parts in control samples. The concentration of lead, cadmium and iron found in the Ori-Ile maize grain was considerably high, but the lead and cadmium level in the Ori-Ile maize root was the highest. According to Goldsbrough *et al* (1995), uptake of toxic metals in plants along with vital elements occurs primarily through the root system. This explains why the concentration found in the root of the Ori-Ile maize was significantly high.

The highest concentration of iron was found in the Ori-Ile maize leaf. According to Aliu *et al* (2013), maize leaf is an active site of photosynthetic activities which is the primary location of food production. This explains why iron concentration in the leaf area was high since iron is essentially required for photosynthesis. Iron is an essential nutrient for plants and it functions to accept, donate electrons as well as plays important roles in the electron-transport chains of photosynthesis and respiration (Connolly and Guerinot, 2002). Plant chlorophyll allows sunlight to change kinetic energy to potential energy and as such, according to Aliu *et al* (2010) leaf area could play an important role in the accumulation of organic materials. But iron is toxic when it accumulates to high levels and can act catalytically via the Fenton reaction to generate hydroxyl radicals, which can damage lipids, proteins and DNA (Connolly and Guerinot, 2002).

High levels of lead, cadmium and iron in Ori-Ile maize parts could only be attributed to contamination of the soil on which the maize plants were grown, since the maize was cultivated in soil of the gradient point direction with the highest heavy metal concentration. Cunningham and Ow (1996) stated that plants can thrive in soil contaminated to levels that are often orders of magnitude higher than current

regulatory limits. The distribution of the heavy metals in this residential plot could only be as a result of its close proximity to the battery waste dumpsite. The concentration of lead, cadmium and iron in soils of the gradient point directions especially along the East where the maize was planted, was very high. Plant uptake capacity strongly varies, and it depends on soil metal concentrations, pH values, among others (Huang and Cunningham, 1996).

Olusoga and Osibanjo (2007) obtained similar lead and cadmium concentrations in their study at Olodo area on metals in plant species found at dumpsite as: Pb (32.6-295.3 mg Pb/kg dry weight), Cd (0.93-56.14 Cd/kg dry weight) and those found in farmland as: Pb (31.8-88.75 mg Pb/kg dry weight), Cd (N.D.-29.40 mg Cd/kg dry weight). Their results showed that the concentrations exceeded normal range of lead and cadmium in plants. Also, the range fall within critical concentrations of these two metals in plants (Bowen 1966; Lepp 1985; McLean *et al* 1987 and Holdgate 1979). The results obtained in this study compares well with the results reported by Olusoga and Osibanjo (2007) for cadmium while lead level was slightly higher.

The effect of active uptake of lead, cadmium and iron by maize seedlings during the growing process could be similar to the observation of Aliu *et al* (2013). According to Aliu *et al* (2013) in their study on the effects of some heavy metals in some morpho-physiological parameters in maize seedlings; the exposure of maize seedlings to lead, cadmium and mercury resulted in a reduction of chlorophyll and carotene content in leaves compared to the control and this affected the leaf area of the maize seedlings. They reported that some maize types are more tolerant to heavy metal toxicity than others. It is possible that the maize grown in this study could have thrived in the Ori-Ile contaminated soil, due to tolerance to heavy metal toxicity, non-bioavailability of the toxic metals to the maize in spite of their presence in the soils and or the threshold of the metal toxicity had not been reached.

Heavy metals can affect plant growth and production in a multiple way by inhibiting a number of physiological processes in plants (Aliu *et al*, 2013). Lead and cadmium are among the heavy metals shown to cause disturbance in plant ion balance by Wallace *et al* (1992) and Barcelo *et al* (1986) as well as in plants water balance; this eventually results in interference with protein metabolism through influencing nitrate and sulphate reduction (Nussbaum *et al*, 1988; Hernandez *et al*, 1997).

Similarly, according to Godzik (1993), maximum lead content was found in senescing leaves while the minimum lead content was found in young leaves. This phenomenon explains that, heavy metals could increase in concentration in storage parts of plants as the plants increases in age. The presence of heavy metals causes stress and inhibits or slows the growth processes of plants (Stiborova *et al*, 1987; Rascio *et al*, 1993), which was also observed in this study.

Result presented by Burzynski (1987), showed that lead inhibits chlorophyll synthesis by causing impaired uptake of essential elements by plants. Therefore, the uptake of lead by Ori Ile maize could be detrimental to the maize plant by hindering the uptake of the essential mineral element needed by the maize. Results by Antosiewicz (1992) showed that the high lead content reduced vascular tissues, but this order can vary with plant species.

Different results reported in literature have shown quite a lot of effects resulting from exposure to heavy metals including lead, cadmium and iron. Results reported by Saderi and Zarinkamar (2012) for concentration of lead and cadmium showed that increased concentration to 180 µM resulted in reduced shoot length by 79.30 % and 83 %. Nocito *et al* (2006) also found that cadmium can cause reduction of coleoptiles, causing clorosis. However, Grejtovsky *et al* (2008) and Seregin and Kozhevnikova (2008) reported that some plants can tolerate even high concentrations of different metals without visual symptoms of toxicity and this explains the reason why some maize plants grew well among the cultivated Ori-Ile maize.

Aliu *et al* (2013) in their study on the exposure of maize seedlings to Pb, Cd and Hg observed that the leaf area had the highest values of the heavy metals at a percentage value of 82.01%. though the result obtained in this study indicated that the root had the highest concentration for lead and cadmium, the concentration found in the leaf was also significantly high. They observed that the exposure of the maize seedlings to the metals resulted in a reduction of chlorophyll and carotenoids content in leaves compared to control. However, the values obtained in this study showed that the leaf had high concentration of Pb and Cd; if further study is carried out in order to ascertain the detailed effects with the leaf part of the studied maize, there could be similar effects as reported by Aliu *et al* (2013) on the chlorophyll and carotenoid contents of the studied Ori-Ile maize.

Metal hyper accumulating species have been identified in at least 45 plant families and individual species can accumulate different metals (Mohammad *et al*, 2012) and the heavy metals contents in plant material are not always directly proportional to heavy metal content in soil (Tomas *et al*, 2012) except in some unique cases. For instance, some results reported by Malecka *et al* (2012) indicated that lead concentration in the exposed plant increased as the concentration in the soil increased. However, the results of this study affirmed maize as a significant accumulator for lead, cadmium and iron. Results obtained in this study likewise showed that the concentrations of cadmium is relatively low compared to concentrations of lead. According to Olusoga and Osibanjo (2007), this trace element might be present as impurities in the slag.

Iron concentrations found was significantly less than the level of iron in the control. According to Lenntech (2010), when soils contain little water soluble iron, plants may experience growth problems. He further stated that lime soils are often iron deficit, even when sufficient amounts of iron were present. This is because of the generally high pH value, which leads to iron precipitation. The pH value obtained in soils of Ori-Ile dumpsite environment was acidic and it could be that the maize plants had easy access to the iron and as such absorbed significant concentration from the soil. Iron toxicity is primarily pH related and as with some other nutrients, the visible symptoms of iron toxicity are likely to be a deficiency of another nutrient (Spectrum analytic, 2013).

Excessive accumulation of heavy metals in soils may not only result in soil pollution or contamination, but can also lead to elevated heavy metal uptake by plants, and thus affect food quality and safety (Muchuweti *et al*, 2006). Heavy metal accumulation in soils and plants is of increasing concern due to the potential human health risks (Singh *et al*, 2010; Aliu *et al*, 2013). This eventually leads to food chain contamination which is one of the important pathways for the entry of these toxic pollutants into the human body (Khan *et al*, 2008; Wilson and Pyatt, 2007).

However, among toxic metals, lead and cadmium appear to be the most dangerous to the environment (Malkowski *et al*, 2005). They also usually cause growth inhibition, ion uptake and transport disturbances, enzyme activation or inhibition, among others (Fargasova, 2001; Geebelen *et al*, 2002). So, since the toxic heavy metals concentration in the most consumed part of the experimental maize are high, there is

tendency of these metals being transferrred to both animals and humans that consume regularly the contaminated maize parts. This may result to several health effects, if bio-accumulated.

5.4.2 Transfer Factors and Pollution Load Indices for Lead, Cadmium and Iron in the Cultivated Maize Parts

Transfer factors are accumulative factors in plants, which are usually calculated and used as basis for interpreting the ability of plants to accumulate different metals (Agunbiade and Fawale, 2009). The calculated transfer factors (TF) and pollution load indices (PLI) of lead, cadmium and iron in the cultivated maize parts of Ori-Ile study site showed the exact level of accumulation of the metals in the cultivated maize and helps in revealing the extent of transfer of the metals from soil to the maize parts.

The TFs and PLIs calculated showed higher values of lead, cadmium and iron in the root part of the maize than the other maize-parts. This was followed by that of leaf, maize grains and stem in that order. The TFs and PLIs of the maize root further revealed that the root actively absorbed these three heavy metals into the maize plant. This may be due to the cationic property of the metals and their ability to replace the essential mineral nutrients required by the maize. This is corroborated by the explanation of Fairbrother and Kapustka (1997) that nutritional requirement or deficiency causes greater uptake and retention of metals. Uptake by plants usually occurs in the root part, hence the transfer values obtained for the maize root.

The transfer factors of the maize root may be further enhanced by the soil pH, which was acidic. According to McKim and Erickson (1991), environmental parameters like pH can affect transfer. Barron (1990) stated that the effects of environmental conditions on uptake and transfer can be dramatic. Although the TFs and PLIs values obtained for the maize-root was the highest, those for lead, cadmium and iron in the maize grains also indicated a significant transference of the three studied metals within the grains. This may be due to the fact that the active uptake of the metals from the soil required a complementary utilization and storage of the excess absorbed elements for future utilization. Hence, the grain, leaf and stem of the maize could serve to either utilize the absorbed metals or bio-accumulate and bio-concentrate it as revealed in this

study; thereby serving as a link through which the toxic metal could be further transferred to other consumers along the food chain.

The TFs and PLIs showed that cadmium was the most absorbed, transferred and accumulated metal of the three studied metal followed by lead and iron in the order Cd > Pb > Fe. Cadmium had been reported to be easily absorbed by plants (Sheng *et al*, 2001; Wang, 2001). This aspect was proved in this study, by the observed transfer factors of cadmium in maize being noticeably the highest. According to U.S. EPA (2002a) and Adams *et al* (2000), the transfer factors could decrease with an increase in exposure concentration or increase with a decrease in exposure concentration.

The TFs and PLIs of the maize parts provided a confirmatory picture of the capacity of maize to accumulate lead, cadmium and iron. However, all maize parts TF values obtained showed low-level of lead, cadmium and iron bio-accumulation and transfer in maize since the values obtained were less than 1 (TF < 1 = low) while the PLI values showed that lead and iron loads was at the baseline whereas there was active uptake and accumulation of cadmium. Nonetheless, the maize-root concentration showed effective phyto-extraction of lead, cadmium and iron. This further support the view that maize is an hyperaccumulator for heavy metals and is capable of reducing heavy metal load in soil by absorbing, accumulating and concentrating the heavy metal pollutants in its tissue, thus serving as an effective tool in evaluating pollution severity and as a bioremediation agent. This is comparable with the results of metal accumulation reported in literature (Farombi *et al*, 2007; Gillis *et al*, 2004).

Nonetheless, this property could be detrimental if the maize were grown for consumption in highly polluted soils as the case of Ori-Ile study site since it could serve a link of exposure and heavy metal toxicity to both animals and man consumers in the community food chain.

5.5 Assessment of Contaminated Maize Using Broiler Chicks

5.5.1 Growth Parameters of the Broiler Chicks

The weight of the experimental chicks was less than that of the control throughout the experiment. The weight of four-, six- and eight-weeks old experimental broilers was less than those of control by 12.66%, 25.49% and 6.20% respectively. However, there

was no significant variation in shank's length, wing length and bird girth after birds were separated. Lead, cadmium and iron were found in much higher concentrations in the soil and tissues of the maize and as such, they could have replaced the far more important nutritional element like calcium, potassium etc. during absorption of the essential mineral nutrient into the maize. According to Bakalli *et al* (1995), even trace levels of lead in the diet (1.0 mg/kg) can result in growth retardation.

According to Clement *et al* (2010), energy portion of poultry diets represents the largest single dietary ingredient and maize is one of the major sources of energy in poultry diets. Muhammad and Oloyede (2004) and Muhammad *et al* (2004) observed that Aspergillus niger-fermented *Terminalia catappa* seed meal-based diet affected broiler growth due to toxic components of the seeds. Muhammad and Oloyede (2009) observed that Aspergillus niger-fermented *Terminalia catappa* seed meal-based diet affected rat growth due to the seeds toxic components. Also, according to Ledoux *et al* (1992), body weights of broiler fed with fumonisin B1 dramatically decreased with increasing dietary fumonisin B1.

All these further verified the findings of this study and confirms that the feed made from Ikumapaiyi harvested maize to a certain extent contains some heavy metal burdens which rather than supplying the essential nutritional requirement to the chicks body for normal healthy growth, constitute a pathway through which the toxic non-essential heavy metals of the polluted community could get into the living system of the broilers and local chicks. Thus, when the essential nourishment is not supplied, the resultant effect is the reduction in weight of the exposed category compared to control, which ultimately affected their growth rates and growth patterns.

5.6 Experimental Broiler Chicks and Control

5.6.1 Lead, Cadmium and Iron in the Skin, Liver, Femur and Plasma of Experimental Broiler Chicks and Control

Results obtained showed significantly high concentrations of lead and cadmium in parts of experimental broilers analyzed than was found in the control though iron was found in less concentration in experimental broilers than in the control. It has been reported that non-essential elements could be transferred through food chains (Rogival *et al*, 2007; Ma *et al*, 2007). According to Bakalli *et al* (1995), lead is toxic to

chickens at much lower levels than previously recognized and lead poisoning remains a serious problem because consumed lead gets released into the system slowly.

In poultry, eco-toxicological researches regarding lead and cadmium accumulation have been focused on the liver because of its key role in the detoxification processes (Kalisinska and Salicki, 2010). In the four and eight weeks old experimetal broilers, liver contained the highest concentration of lead, followed by skin, femur and blood in that order. Liver is known as the organ responsible for active detoxification in the body of any organism. The concentration found in the liver of the four weeks old experimental broilers was the highest compared to the other parts and this could be because the experimental broilers were the first group exposed to the contaminated feed and as such, their bodies tend to detoxify the toxic components using the liver.

Accumulation of lead in the liver of broiler has been reported in literature (Erdogan *et al* (2005), Bakalli *et al* (1995), Khan *et al*, 1993). Ismail and Abolghait (2013) reported similar high lead concentrations in the liver samples of the chicken they studied and it exceeded the maximum limit of 0.5 ppm in the Codex Alimentarius International Food Standards. Altogether, the concentration of lead in all the parts of the four and eight weeks old experimental broilers were significant.

The six weeks old experimental broilers had the highest concentration of lead in the skin, followed by femur, liver and plasma in that order. This, according to the report of Ismail and Abolghait (2013) and Bakalli *et al* (1995), may be due to the fact that lead consumed by chicken is redistributed within the body and accumulated in the soft tissues, bones and eggs. Chicken skin is also known for storage especially in the subcutaneous layer. Ismail and Abolghait (2013) and Vengris and Mare (1974) also obtained a significant concentration of lead in the skeletal muscle of chicken they studied. Also, Vengris and Mare (1974) obtained a significant level of lead in the bone, liver and kidney of chicken they studied.

The concentration of lead found in the different analyzed parts of the four - eight weeks old broilers were significantly lower than 0.5000 ppm obtained for liver and 0.2800 ppm obtained for muscle by Ismail and Abolghait (2013). However, the values were more than 0.0060 ppm and 0.0069 obtained by Tahvonen and Kumpulainen (1994) and Gonzalez-Weller *et al*, 2006 in the chicken they studied except for the

levels in the six weeks old liver and plasma as well as the eight weeks old skin, femur and plasma. Some of the values obtained in this study were similar to the range obtained for lead in chicken granules and gourmet powder by Shi *et al* (2005).

Many lead poisoning cases are of a chronic nature. Since toxic lead residues were found to be in high levels in the chicken livers and its bioaccumulation could lead to serious human health problems among consumers; excessive consumption of livers originating from chicken raised in lead contaminated environment should be discouraged.

In the four weeks old experimetal broilers, liver and skin contained the highest concentration of cadmium, followed by femur and plasma in that order. The concentration of cadmium in the six weeks old experimental broilers was highest in the femur, followed by the skin, liver and plasma in that order; while in the eight weeks old experimental broilers, the skin had the highest concentration of cadmium followed by that of the liver, femur and plasma in that order. Anthropogenic cadmium is a priority environmental pollutant and evolved health hazard (Revitt *et al*, 2013). Cadmium is able to induce bone damage (Itai-ltai) (Ciobanu *et al*, 2012).

The concentration of cadmium found in the different analyzed parts of the four - eight weeks old broilers were significantly lower than 0.041 ppm obtained for liver by Ismail and Abolghait (2013). However, the values were more than the values obtained for cadmium by Tahvonen and Kumpulainen (1994), which was below detection limit and 0.00168 ppm obtained by Gonzalez-Weller *et al*, 2006 except for the levels in the plasma of the six weeks old chicks. Some of the values obtained in this study were also higher than the range obtained for lead in chicken granules and gourmet powder by Shi *et al* (2005).

The concentration of iron found in the experimental broilers may be due to the presence of lead and cadmium in the diet of the experimental broilers. Lead and cadmium are cations like iron and they could easily replace iron in the body when absorbed into the body. Iron is needed in the body because the blood hemoglobin is dependent upon the availability of iron for its formation and an insufficiency of iron will in turn result in insufficient hemoglobin which leads to a medical condition called anaemia (Green *et al*, 1968). But, the toxic buildup of iron leads to death usually from

heart failure and the inability of the body to excrete excess iron could result in iron accumulation in the body with damaging result (Nathan and Nisbet-Brown, 2008). However, in this study, though the values obtained for iron concentration was high; it may not constitute any harm to the chicks since iron is among the essential mineral element that their body requires.

This study is corroborated by the study of Bakalli *et al* (1995) on magnitude of lead toxicity in broiler chickens in which lead additions to diet resulted in a dose-related increase of lead in blood, kidney, liver and tibia bone. Similarly, study by Dwiloka *et al* (2012) revealed that significant bioaccumulation of lead and cadmium occurs in broilers fed with different diets, one of which consists of Nevrata Croatian river fish contaminated with lead and cadmium pollutant. After a 4-week exposure to cadmium, lead and mercury by Bersenyi (2003), broiler cockerel concentrations of the metals in blood were significantly elevated at $P<0.001$.

Eco-toxicological researches displayed that sea-birds, which have their own breeding grounds in the arctic and subarctic regions of the northern hemisphere, have high levels of cadmium, which accumulates mainly in the kidneys at highest concentration and then in the liver at relatively lesser concentration (Kalisinska and Salicki, 2010). In the study with other animals, Lansdown and Sampson (1996) administered a cadmium chloride solution to the shaved skin of rats daily for 10 days and the cadmium concentration in blood, liver and kidney increased, thus indicating percutaneous absorption (Lansdown and Sampson, 1996). The cadmium concentrations in most tissues increase with age and the highest concentrations are generally found in the renal cortex, but excessive exposures may lead to higher concentrations in the liver (WHO, 1992).

For certain elements, bioaccumulation is required for organism health and normal function while in other situations, bioaccumulation produces residues in plants and animals that cause direct toxicity to the exposed organism or indirect toxicity to consumers (Kern *et al,* 2000). Furthermore, the metabolism of an essential element can affect the metabolism of a non-essential toxic metal, as in the case of calcium and lead in the central nervous system (Kern *et al*, 2000). Birds are good sentinel species because they are observable, sensitive to toxicants, and live in different trophic

positions (Custer and Osborn, 1977; Walsh, 1990; Prichard *et al*, 1997; Spalding *et al*, 1997).

The correlation coefficient matrices further indicated that after the exposure, in the four weeks old broilers, there was a gradual increase in lead concentration as the birds' age increase (from two - four weeks), however, due to bioaccumulation, six weeks old lead content was much more higher in the plasma while distribution and storage of potent toxic substances in short and long time storage organs such as fat and bone, has led to reduction in the concentration of lead in the blood of the eight weeks old broilers. Lead increase also result in an increase in iron and cadmium content across all ages and vice versa.

5.6.2 Bio-accumulation Factors and Pollution Load Indices for Lead, Cadmium and Iron in the Skin, Liver, Femur andPlasma of Broiler Chicks

The bio-accumulation factors (BaF) and pollution load indices (PLI) of the lead, cadmium and iron in the skin, liver, femur and plasma of broiler chicks were determined to show the accurate level of accumulation of the metals within the different parts of the broiler chicks. Lead and cadmium BaF and PLIs values for all the broiler chicks were less than 1and this indicated that these metals had low level of absorption and accumulation in the different internal organs of the chicks that was assessed.

The BaF and PLIs for lead and cadmium in the skin, liver, femur and plasma showed that lead is more accumulated out of these two metals and liver has the highest BaF and PLI for both metals while plasma had the least BaF and PLIs for lead and skin had for cadmium respectively. However, BaF and PLIs for iron in all chicks was greater than 1(Fe>1) and this indicated high level of absorption and accumulation of iron in the tissues of the chicks. Similarly, the liver had the highest BaF and PLIs for iron while skin had the least.

According to Agunbiade and Fawale (2009), lead and cadmium are of serious concern and adequate control of their sources is paramount because of their negative impact on biotic organisms and the ecosystem at large. These two metals affect metallothionine, a cystein-rich, low-molecular weight, metal-binding protein (Perceval *et al*, 2002). They also affect the hormonal activity in living organisms (Laflamme *et al*, 2000). Lead, at

trace concentrations lower than the observed concentration in this study; has caused anaemia, brain damage, anorexia, renal failure, mental deficiency, vomiting and even death in human (Bulut and Baysal, 2006; Low *et al*, 2001). Similarly, these two heavy metals have been reported to have high affinity for the SH groups in proteins, haemoglobin, enzymes/hormones and this affects their activities (Manahan, 1992).

Though, previous studies by Agunbiade and Fawale (2009), Sheng *et al* (2001) and Wang (2001) reported that cadmium was easily absorbed by plants, this study have shown that lead also exhibit similar absorption ability into the maize tissue. The Transfer factors and pollution load indices of the maize parts showed a clear picture of the capacity of *Zea mays* to accumulate lead and cadmium while the BaF and PLIs in the experimental broilers fed with formulated feed from Ori-Ile maize showed that uptake and absorption of these heavy metals in food consumed is very possible while the consumers' health is at risk due to their persistent and non-degradable properties.

5.7 Ori-Ile Free-Range Local Chicks and Control

5.7.1 Lead, Cadmium and Iron in the Skin, Liver, Femur and Plasma of Free-Range Local Chicks of Ori-Ile Olodo Community and Control

Results also showed significantly high concentration of lead and cadmium in Ori-Ile free-range chicks skin, liver, femur and plasma analyzed than control. Iron was found in less concentration than the control. The liver of the free-range chicks had the highest concentration of lead, followed by skin, femur and plasma in that order. Liver is known as the organ responsible for active detoxification in the body of any organism. This explains why the concentration found in the liver of the free-range chicks was the highest compared to the other parts.

The use of birds for toxicity studies through their food goes way back in history. Morgan *et al* (1975) dosed newly-hatched Japanese quail with lead acetate in the diet at 10, 100, 500, and 1000 mg lead/kg for 5 weeks and Edens *et al* (1976) investigated the effects of dietary lead acetate on reproductive performance in Japanese quail *(Coturnix coturnix japonica)* (WHO, 1989). Damron and Wilson (1975) conducted a series of studies to determine the toxicity of lead, in various forms, to bobwhite quail *(Colinus virginianus)* giving them varying dosage of lead acetate in their diet while Johnson and Damron (1982) also fed led acetate to white Chinese geese (WHO, 1989).

Lead in blood is a good indicator of newly exposure, while chronic exposure can be estimated when concentrations in accumulator tissue(s) are available (Muhsin *et al*, 2010). Determination of the blood Pb level alone cannot indicate the toxicity of Pb, since each individual has different degrees of tolerance of Pb (Marcus, 1985).

Accumulation of lead in the liver of chicken has been reported in literature (Erdogan *et al* (2005); Bakalli *et al* (1995); Khan *et al*, 1993). Ismail and Abolghait (2013) reported similar high lead concentrations in the liver samples of the chicken they studied and it exceeded the maximum limit of 0.5 ppm in the Codex Alimentarius International Food Standards. The concentration of lead found in the different analyzed parts of the four - eight weeks old broilers were significantly higher than 0.5000 ppm obtained for liver and 0.2800 ppm obtained for muscle by Ismail and Abolghait (2013). However, only the value obtained for lead level in liver in this study was more than 0.0060 ppm and 0.0069 obtained by Tahvonen and Kumpulainen (1994) and Gonzalez-Weller *et al*, 2006 in the chicken they studied. Some of the values obtained in this study falls within the range obtained for lead in chicken granules and gourmet powder by Shi *et al* (2005).

Toxic lead residues were found to be in high levels in the chicken livers and its bioaccumulation could lead to serious human health problems among consumers; excessive consumption of livers originating from chicken raised in lead contaminated environment should be discouraged.

The highest concentration of cadmium in the free ranged chicks was obtained in the skin, followed by that of liver, femur and plasma. Anthropogenic cadmium is a priority environmental pollutant and evolved health hazard (Revitt *et al*, 2013). Cadmium is able to induce bone damage (Itai-ltai) (Ciobanu *et al*, 2012). Ecotoxicological researches displayed that sea-birds, which have their own breeding grounds in the arctic and subarctic regions of the northern hemisphere, have high levels of cadmium which accumulates mainly in the kidneys at highest concentration and then in the liver at relatively lesser concentration (Kalisinska and Salicki, 2010).

The concentration of cadmium found in the different analyzed parts of the free range chicks were significantly higher than 0.041 ppm obtained for liver by Ismail and Abolghait (2013). Also, the values were more than the values obtained for cadmium by

Tahvonen and Kumpulainen (1994), which was below detection limit and 0.00168 ppm obtained by Gonzalez-Weller *et al*, 2006 in the chicken they studied. Some of the values obtained in this study were also higher than the range obtained for lead in chicken granules and gourmet powder by Shi *et al* (2005).

The highest concentration of iron was found in the liver and was significantly less than that of the control. This was followed by the concentration in the plasma, femur and skin in that order. Iron is an essential element and it is required by the body in higher amount. Hence the concentration obtained in this study may not lead to toxicity if it is metabolized.

The correlation coefficient matrices further indicated that an increase or decrease in lead concentration will simultaneously result in an increase or decrease in iron concentration in all the local residential chicks of Ikumapaiyi assessed except for iron and cadmium concentrations in which an increase in one does not in any way contribute to either increase or decrease of the other.

5.8 Haematological Values of the Blood of Broilers and Free-Range Local Chicks

The use of blood examination in assessing health status of animals has been documented (Muhammad *et al*, 2000; Owoyele *et al*, 2003; Muhammad *et al*, 2004; Muhammad and Oloyede, 2009). Blood plays a vital role in physiological, nutritional and pathological status of organisms (Muhammad *et al*, 2000; Muhammad and Oloyede, 2009). The result of this study showed that PVC, RBC, Hb, MCH and MCV are significantly (P=0.05) decreased while WBC is increased in the plasma of 4-weeks and 6-weeks old experimental broiler chicks. All values obtained were less than the control.

All the haematological parameters of the 8 weeks old broilers' plasma were not significantly less than control (p=0.05) and were comparatively normal like the control. The PCV, RBC, Hb, MCV, MCH and ESR were significantly less (P=0.05) in the blood of the Ikumapaiyi local chicks though the blood parameter MCHC had the same value as that of the control. However, those of the control broiler chicks of the same age were significantly higher (P=0.05). Also, the white blood indices like WBC, lymphocytes and eosinophils were higher than those of control.

Bersenyi (2003) reported that RBC, HB, and HCT are significantly ($P<0.05$) decreased while MCH and MCV are increased by Pb burden in broiler cockerel exposed to Cd, Pb, Hg and Ni. Similarly, Muhammad and Oloyede (2009) also observed that the haematological parameters were significantly less than control, in broiler fed Aspergillus niger-fermented *Terminalia catappa* seed meal-based diet. They attributed this to the effect of seed components on haematological parameter. Hence, it can be inferred that the heavy metal components of the maize fed to the experimental broilers could also be responsible for the reduction in the haematological parameters compared to control and pre-assessed broilers.

Significant reductions in haemoglobin, PCV and RBC contents of blood is an indication that oxygen carrying capacity of birds' blood could be reduced, a condition known as anaemia (Aduloju, 2000). Reduction in haemoglobin may be accompanied by a fall in the red cell count (RBC) and packed cell volume (haematocrit) (Aduloju, 2000). The anaemia could either be pernicious type in which the bone marrow ceases to make RBC or haemolytic type in which there is an intravascular explosion of RBC, a condition that could be made worse by exposure to toxic substances, high temperature and poor diet. Also, Muhammad and Oloyede (2009) reported that very low readings for RBC, heamoglobin and hematocrit can indicate anaemia. Reduction of MCV, MCH and MCHC can also indicate that there may be iron deficiency which is likely to become severe as exposure increases.

The significant reductions in the WBC and lymphocytes would predispose the animals to reduced immunological responses and infections (Muhammad and Oloyede, 2009). Usually, very low WBC can be caused by problems with bone marrow (Roberts, 1976). However, the implication of an increase in the WBC count (high WBC) usually means that body is fighting an ingested toxic substance or infection because main function of white blood cell is to combat and prevent infection (Roberts, 1976).

Agrawal and Mahajan (1980) reported that a significant decrease in WBC of blood indicates a decline in production of defensive mechanism to combat infections. Hence, this also confirms that an increase in the WBC of the broiler chicks would mean that there is an increase in the production of defensive mechanism to combact a foreing substances perhaps as this case applies, the heavy metal in the feed. Reduced WBC is a situation which would naturally make the animals more susceptible to various

physiological stress resulting in diseases, greater mortality and poor growth (Agrawal and Mahajan, 1980). In this case, an increase could mean the animal is striving to survive the exposure to the toxic substances by secreting more defensive resources to overcome the situation.

Avian blood consists of the erythrocytes (Red blood cells), leukocytes (white blood cells) and thrombocytes (similar to platelets in mammals) and these help in the transport of nutrients, oxygen, carbondioxide, waste products, hormones and heat (Avian Physiology Lecture, 2012; Schepelmann, 1990). All these components of the avian blood form the basis of the parameters that are assessed as haematological parameters. According to Muhammad and Oloyede (2009), haematological parameters are those parameters that are related to the blood and blood forming organs.

It had been reported that biochemical changes as a result of toxins have effects on haematological parameters (John, 1998; Karnish, 2003; Levene and Gorgen, 2003; Muhammad and Oloyede, 2009). Due to vital role of blood, it is essential that nothing affects it or any vital organ contributing to its well being and function (Schepelmann, 1990).

The haemoglobin (Hb) is made by the red blood cells and it is between 8 - 12 g/dl in chicken blood. All the values obtained for the broilers and free-range chicks haemoglobin in this study were within this range. The amount of haemoglobin in the red blood cells is the mean corpuscular haemoglobin (MCH) and is an approximate value of about 50 pg/cell while the relative volume of red blood cell's haemoglobin is the mean corpuscular haemoglobin concentration (MCHC) and is an approximate value of 25% (Avian Physiology Lecture, 2012). All the MCH values obtained were significantly lower than the value stated above while those of the MCHC were very significantly higher than the value stated above.

WBCs can either be agranulocytes (monocytes: 5-15% WBCs and lymphocytes – 60 – 80% WBCs) and granulocytes (heterophils – 20 – 30% WBC, eosinophils – 1-3% WBC and basophils: 0.5 – 2% WBC) (APL, 2012). The values obtained for monocyte in this study for both the broiler and local chicks were significantly lower than the values stated above while that of the lymphocytes was similar to the range stated for the six weeks old experimental broilers but less than the values for the eight weeks old

experimental broilers and free range chicks. The values obtained for heterophils for both the experimental broilers and free range chicks were very much higher than the range given above.

WHO (1989) reported similar observations in the study by Damron *et al* (1969) on four-weeks-old broiler chicken fed with feed containing dietary lead acetate at levels between 10 and 2000 mg lead/kg for 4 weeks. Muhammad and Oloyede (2009) also reported similar effects of *Aspergillus niger*-fermented *Terminalia catappa* seed meal-based diet on the haematological parameters of broiler chicks. The effects of feeding broiler chickens with millet, low tannin and high tannin sorghum based diets compared to maize- based diet on the carcass measurements and blood constituents was investigated in the semi-arid zone of Nigeria by Clement *et al* (2010) and his report had similar trend as this study.

In all the broiler chicks' plasma assessed, PCV had a positive significant correlation with RBC, HB, heterophilis, as well as lymphocytes and it had a negative significant correlation with WBC and ESR. RBC had a positive significant correlation with HB only but it had a negative significant correlation with MCV, MCH and ESR while WBC only had a negative significant correlation with PCV and Hb. Hb had a positive significant correlation with PCV, RBC, heterophilis and lymphocytes but it had a negative significant correlation with WBC and ESR whereas MCV had a positive significant correlation with MCH only but it had a negative significant correlation with RBC. MCH had a positive significant correlation with MCV only but it had a negative significant correlation with RBC while MCHC had no significant correlation with all the other blood parameters.Heterophilis had only positive significant correlation with PCV, HB, and lymphocytes while Lymphocytes also had only positive significant correlation with PCV, HB, heterophilis and monocytes. Monocytes only had significant relationship with lymphocyte while Eosinophils had no significant correlation with all the other blood parameters and ESR had only negative significant relationships with PCV, RBC and Hb. A positive significant correlation shows that an increase in the relating haematological parameter would result in an increase in the comparative haematological parameters and vice versa while a negative significant correlation shows that an increase in the relating haematological parameter would result in a decrease in the comparative haematological parameters and vice versa.

This implies that the absorption or uptake of the heavy metals by maize from the studied Ori-Ile top soils, which had very high concentrations of the three metals and the subsequent transfer of the metals into the chicks' system was responsible for the significant effects on the blood parameter especially because the plasma of both the broilers and free range domestic chicks have significant level of the metals.

5.9 Histopathology of the Liver and Kidney of Broilers and Free-Range Local Chicks

The histopathological examination showed that there is a gradual but progressive effect on the liver and kidney of the broilers as well as local chicks examined. Liver is part of digestive system and performs different essential functions such as fats digestion, storing reserves of nutrients, filtering poisons and wastes from blood, synthesizing a variety of proteins as well as regulating the levels of many chemicals found in the bloodstream. According to Lag (1993), iron accumulates in the liver causing siderosis. Siderosis is the accumulation of iron in tissues and damage to the storage organs. The liver can regenerate or grow back cells that have been destroyed by some short-term injury or disease but if liver is damaged repeatedly over a long period of time, it may undergo irreversible changes that permanently interfere with its function (Lag, 1993). The kidney however has a primary function of removal of poisonous wastes from the blood, a process usually referred to as selective re-absorption.

The high incidence of histological changes in the liver and kidney is a demonstration of the poor environmental quality (Lidia *et al* 2011). The result of the histopathological assessment revealed that the liver of the four weeks old broilers showed cases of diffuse vacuolar degeneration with areas of necrotic hepatocytes and loci of cellular aggregation by mononuclear cells while the kidney showed mild interstitial congestion though no visible leision was seen. The liver of six weeks old had central venous and portal congestion, portal fibrosis as well as cases of mild cellular infiltration with areas of severe diffuse hepatic degeneration and necrosis while the kidney showed mild renal cortical congestion though no visible leision was seen as well.

In the eight weeks old broilers, the liver had loci of severe cellular aggregation by macrophages and lymphocytes as well as mild periportal hepatic degeneration. It also

had necrosis with very mild cellular infiltration by mononuclear cells while the kidney had fibrosis at the interstitium and very much reduced tubular lumen. The kidney also showed severe cortical congestion with locus of cellular aggregation at the interstitium by the mononuclear cells. In the local Ikumapaiyi chicks assessed however, the liver showed cases of masssive perivascular cellular infiltration by mononuclear cells and severe diffuse hepatic degeneration as well as necrosis while their kidney had severe renal cortical congestion with massive interstitial haemorrhages of the renal cortex.

This is supported by the study by Kumar and Balachandran (2009), which revealed degenerative and necrotic changes in liver, kidneys, intestine, pancreas, heart, pectoral muscle, spleen and bursa of Fabricius of all toxin fed broiler chickens. Results of study by Arija *et al* (2000) showed that the birds fed 150 g kg−1 of FFSK showed a shortening and thickening of the villi, hyperplasia and vacuolar degeneration of enterocytes, and hypertrophy and hyperplasia of goblet cells. The results of study of Bersenyi (2003) confirmed pathological focal fatty infiltration in livers and slight tubulonephrosis developed in kidneys of rabbits. According to him, even 50 mg/kg of Ni damaged the liver parenchyma and induces pathological focal fatty infiltration in broilers and rabbits.

Histopathological changes observed by Krishnamoorthy *et al* (2007) in toxin-fed broiler chicken include periportal fibrosis, mononuclear cell infiltration, necrosis of hepatocytes and bile duct hyperplasia in the liver while the chicken kidney showed tubular epithelial degeneration and necrosis. All these observations agree with those seen in this study and this further confirms that gradual but continuous exposure to feed with varying levels of heavy metals particularly lead, cadmium and iron as in this study over a prolonged period could result in sub-lethal damages to essential parts of the chicks body, which are responsible for detoxification as seen in this study of the broilers' and local chicks' liver and the kidney.

The histology of control broilers kidneys indicated distinct and normal size of proximal and distal conducting tubules of glomerulus with connective tissues. But, the experimental broilers kidneys showed damaged proximal and distal tubules. Tubular cell necrosis usually is due to ischemic and nephrotoxic agents. Vasoconstriction and reduced blood flow causing ischemia resulted in tubular cell damage (Confer and Panciera 2001). Dilation of the lumen of the kidney tubules, necrotic changes and

degeneration of glomerulus have been reported in *Labeo rohita* (Hamilton, 1822) exposed to hexachlorocyclohexane (Dass & Mukherjee 2000) and *Cyprinus carpio* Linnaeus, 1758 exposure to deltamethrin (Cengiz, 2006). The necrosis of the renal tubules affected the metabolic activities and advertises metabolic irregularities in fish (Yokote 1982).

Alterations in the liver may be useful as markers that show former exposure to environmental stressors (Velmurugan *et al* 2007) since it is the main organ for detoxification (Soufy *et al* 2007). In the present study, liver revealed various degenerative changes. The most demonstrated one was vacuolar degeneration. Control broilers livers showed large polygonal hepatocytes, which were separated by blood sinusoids and each hepatocyte showed a distinct round and central nucleus with nucleoli and granular cytoplasm. Experimental broilers livers showed changes in its architecture. The hepatic cell diameter was changed, extensive cytoplasmic vacuolization was seen and nuclei become unusual. These histopathological alterations may affect the functional efficiency of the liver, leading to malfunctioning of several organ systems of the chicks.

Gingerich (1982) revealed that the vacuolization of hepatocytes might indicate an imbalance between the rate of synthesis of substances in the parenchymal cells and the rate of their release into the circulation system. On the other hand, Eder and Gedigk (1986) suggested that oxygen deficiency may be the most common cause of the cellular degeneration in the liver. The fatty degeneration changes in studied liver may be caused by decline in the rate of utilization of energy stock (Desai *et al* 1984).

In previous studies, necrosis and hemorrhagia (Cengiz and Unlu 2006) have been reported, which is consistent with the current study. In addition, increased numbers of inflammatory cells mainly lymphocytes and macrophages have also been reported (Cengiz and Unlu 2006) and this is consistent with this study. The inflammation involves a complicated series of homeostatic mechanisms involving the immune, nervous and circulatory systems in response to tissue damage or infection (Sharkey, 1992). Based on the fact that the liver is an essential organ with detoxification role in body, any alteration in environmental conditions and nutrition may give rise to liver lesions.

According to Harrison *et al*, (1993), lead (Pb) is also known to have toxic effect on the nervous system, kidney and liver. Lead (Pb) is known to cause kidney damage. Some of the effects are reversible, whereas chronic exposure to high Lead (Pb) levels may result in continued decreased kidney function and possible renal failure. Renal effects have been seen among the general population when more sensitive indicators of function were measured (WHO, 1995).

With increasing exposure intensity, an increasing proportion of the absorbed cadmium is stored in the liver (WHO, 1992). Cadmium absorbed from the lungs or the gastrointestinal tract is mainly stored in the liver and kidneys, where more than half of the body burden will be deposited (WHO, 1992). Excretion is normally slow, and the biological half-time is very long in the muscles, kidneys, liver, and whole body of humans (WHO, 1992). The main organ for long-term cadmium accumulation is the kidney and in it, the half-life period for cadmium is approx. 10 years (Orlowski and Piotrowski, 2003; Johannes *et al*, 2006). A life-long intake can therefore lead to a cadmium accumulation in the kidney, consequently resulting in tubulus cell necrosis (Johannes *et al*, 2006). Cadmium accumulation in the kidneys leads to dysfunction of the kidney with increased secretion of proteins in urine (proteinuri) and other effects (European Commission, 2002).

Long-term parenteral or oral administrations of cadmium have been found to produce effects primarily on the kidneys, but also on the liver (WHO, 1992). Chronic cadmium exposure primarily affects the kidneys (ATSDR, 2008). Of greatest relevance to human exposure to cadmium are the chronic effects on the kidney. Following long-term exposure, the kidney is the critical organ. The effects on the kidney are characterized by tubular dysfunction and tubular cell damage, although glomerular dysfunction may also occur (WHO, 1992). An increasing cadmium load in the kidney is also discussed to result in a higher calcium excretion, thus leading to a higher risk of kidney stones (Johannes *et al*, 2006).

CONCLUSION AND RECOMMENDATION

The site for this study was Ori-Ile battery waste dumpsite, which was an unapproved open dumpsite specifically for battery wastes from waste contractors of the moribund lead acid battery manufacturing company known as West African Battery Industry. This improper disposal of battery wastes in such developing, poor, residential and semi-urban area like Ori-Ile Olodo area; has attending consequences on the community and its inter-connected ecosystem. There were reports of environmental challenges being faced by the inhabitants along with reports of disease outbreak in relation to heavy metal toxicity, damage to crops, poultry, aquatic life as well as abortions in goats. This led to the closing down of the company by the Federal and State Government. Despite this, the effects of the dumped battery wastes were still persistent in the area.

This present study at Ori-Ile waste dumpsite and surroundings has determined the levels of selected heavy metals, namely lead, cadmium and iron in the topsoil of the waste dumpsite and the surrounding gradient points up to 25 m distance; the underground water, surface water, maize plant and chicks of Ori-Ile Olodo community in order to know the extent to which heavy metal components of the discarded battery wastes have been dispersed, absorbed and accumulated within the biotic and abiotic componentS of the community.

The results obtained in this study has shown that the topsoil samples taken from the waste dumpsite and its surrounding gradient points using predefined sampling points, contained very high and toxic level of lead, cadmium and iron. Apart from this, from cursory observations, the waste dumpsite area was bare with scanty vegetation, despite the fact that the surrounding areas are furnished with diverse arrays of plants.

The concentration of lead, cadmium and iron in the topsoil along the North, South, East and West directions at 5 m intervals from the edge of the waste dumpsite were very high. This may be due to the fact that all these areas were also used as open waste dumpsite beforethe present study was conducted. It could also be due to the spread of the battery waste components to the other parts of the Ori-Ile Olodo community through the dispersal agents such as wind and water erosion or even residents including children. Battery cases were seen within the vicinity of the residents homes that were being used for different domestic activities. This was also confirmed by Adie

and Osibanjo (2009); Iwegbue *et al.* (2006); Chen *et al.* (2009) and Oyediran and Aladejana, 2011.

Apart from this, the dispersal of the wastes' heavy metal components to other parts of the community was also confirmed by the underground water and surface water. The result of the concentration of lead, cadmium and iron in both the underground and surface water showed significant concentration of the metals in the water body. This further showed that these metals were gradually leached into the water sources from the soil which had high concentration of the metals. This calls for urgent attention because lead and cadmium are bio-accumulative in nature and continual exposure of residents to them through the water sources could be detrimental to their health as well as that of their animals.

The result of determination of the selected metals in maize parts indicated that there was active phyto-extraction of lead, cadmium and iron from the soil through the root. The maize root contained the highest concentration of the metals especially lead and cadmium. Maize has been known as hyper-accumulator of heavy metals and this quality of the food crop could be beneficial when it is used for phyto-remediation. However, the consumption of the edible parts of the maize crop, either by residents or by the domestic animals, could lead to bio-accumulation of the toxic metal within the body of the consumer. Thus, maize grown in the vicinity of Ori-Ile battery waste dumpsite is unfit for consumption as it could serve as a route of exposure of residents to lead, cadmium and iron.

The toxicity assessment using the broiler chicks fed with feed formulated from the harvested Ori-Ile maize seeds further showed that there could be absorption of heavy metals from the food consumed. The result obtained had significant concentrations of the metals in the organs of the experimental broilers.This further showed that there is probability of bio-accumulation by higher trophic consumers, in this case the broiler chicks. If the residents of Ori-Ile community raise broilers as a source of income, it means that the transfer and effect of the toxic metals goes beyond the community food chain to affect consumers in the larger community. This study has also shown that chicks have the ability to bio-accumulate metals in their different internal tissues and organs as indicated by the concentration of lead, cadmium and iron in the liver, skin, femur bone and plasma of the chicks.

The concentration of lead, cadmium and iron within the free-ranged chicks were significantly higher than control. Being mostly scarvengers, these free-ranged chicks must have consumed plant and animal materials that were rich in the non-bio-degradable toxic heavy metals and as such, bio-accumulated and bio-concentrated them within their body. In addition, they could also add to their mettallic burder through the consumption of the Ori-Ile water, which also contains significant concentration of the heavy metals. The effects of the bio-accumulation of the heavy metals was seen in the histopathological results of the broiler and free-ranged chicks liver and kidney obtained in this study. Necrosis, severe diffused hepatic degeneration and interstitial haemorrhages are among the observations recorded in both the broilers and free-ranged chicks. This could arise from their exposure to the contaminated feed, water or the environment while the liver and kidney made attempt to get rid of the toxins.

Continuous exposure to these heavy metals in the battery wastes is dangerous to human health. In agreement with USEPA (2011), the health risk of the residents of Ikumapaiyi community could result from their direct contact with the contaminated soil, vapors from the contaminants, consumption of contaminated water supplies either surface or underground, consumption of contaminated cultivated plants like maize as well as consumption of contaminated animal food resources raised within the environment. Also, the presence of these heavy metals' in the food chain in elevated concentrations could affect the quality and safety of the food materials and in turn pose threat to the community's food production and consumption.

In conclusion, the high accumulation of heavy metals found in the soils of Ori-Ile battery waste dumpsite, Olodo, Ibadan bioaccumulated in the maize parts especially the root and in the chicken organs. This raises significant environmental concern and calls for urgent attention and appropriate response in remediating the contaminated area. Contaminants in soils and sediments can move from substrates into food sources for man because of their contact with plants and animals. As such, they could cause unacceptable risks. However, in the meantime, residents should avoid the consumption and sale of food items raised within the Ori-Ile community.

However, though excavation of the waste dumpsite has been carried out, there is need for post excavation geochemical assessment of the waste site and its surrounding biotic

and abiotic ecosystems for better understanding of the type of risk that could arise from past exposure, the scope of the health damage and method to be employed for effective and efficient restoration of the affected ecosystem. Further detailed remediation and decontamination measure should be carried out beyond the waste dumpsite up to about 2km distance, to avoid any outbreak of diseases in the near future because the area is occupied by ignorant residents who have no knowledge of the extent of the effect of the battery waste on their health.

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APPENDICES

Appendix 1: Allowable Standard Tolerance Limits NESREA for Different Samples

Sample	**Soil (mg/kg)**				**Water (mg/l)**				**Groundwater (ug/l)**			
Metal	Pb	Cd	Fe		Pb	Cd	Fe		Pb	Cd	Fe	
NESREA	164	50	nf		0.01	0.005	1.0		15	0.4	nf	

Appendix 2: Concentrations of Lead (Pb) (mg/kg) in Distances within 25m along the Different Gradient Points

Point X Distance	MARCH 2008	MAY 2008	JULY 2008	SEPT. 2008	JAN. 2009	MARCH 2009	MAY 2009	JULY 2009	Mean
C	185.0	105.0	133.0	131.5	185.0	221.5	122.5	172.5	157.0
Rd	4390.0	3300.0	3090.0	7210.0	3940.0	5140.0	2670.0	4450.0	4273.8
E0	4106.7	3056.7	4303.3	6080.0	5516.7	4856.7	3493.3	3396.7	4351.3
E10	4283.3	2980.0	4366.7	5413.3	4313.3	4803.3	3416.7	3916.7	4186.7
E20	3866.7	4073.3	3403.3	4730.0	3963.3	3610.0	2926.7	3633.3	3775.8
E25	2586.7	3443.3	3180.0	4020.0	3800.0	3270.0	2543.3	3283.3	3265.8
N0	4733.3	4253.3	4143.3	7136.7	5570.0	4666.7	2986.7	4060.0	4693.8
N10	5723.3	3993.3	3883.3	6633.3	4716.7	4440.0	2540.0	3563.3	4436.7
N20	4003.3	3663.3	3360.0	4833.3	3906.7	3983.3	2646.7	3030.0	3678.3
N25	3370.0	3360.0	3040.0	4300.0	3266.7	3480.0	2473.3	2676.7	3245.8
S0	3016.7	3093.3	4776.7	6096.7	5436.7	4853.3	3783.3	3770.0	4353.3
S10	3533.3	3440.0	4110.0	5653.3	4490.0	4426.7	3556.7	3896.7	4138.3
S20	3886.7	3016.7	3373.3	5033.3	3716.7	4026.7	2580.0	3266.7	3612.5
S25	3143.3	3280.0	2860.0	3703.3	3526.7	3583.3	2203..3	2800.0	3137.5
W0	3233.3	5000.0	5216.7	6493.3	5826.7	4876.7	3376.7	3563.3	4698.3
W10	3256.7	3736.7	3913.3	5966.7	4936.7	4383.3	3170.0	3346.7	4088.8
W20	3590.0	3706.7	3536.7	5430.0	4413.3	3883.3	2566.7	3006.7	3766.7
W25	3696.7	3276.7	3273.3	4646.7	3166.7	3360.0	2433.3	3076.7	3366.3
Mean Sq.	821.6	522.8	505.0*	999.1	800.8*	369.4*	292.8	251.3	-

Mean Square values with * are significant at $p < 0.05$

Appendix 3: Concentrations of Cadmium (Cd) (mg/kg) in Distances within 25m along the Different Gradient Points

Point X Distance	MARCH 2008	MAY 2008	JULY 2008	SEPT. 2008	JAN. 2009	MARCH 2009	MAY 2009	JULY 2009	Mean
C	3.65	2.40	2.70	0.75	3.65	1.70	1.25	1.60	2.21
Rd	235.00	170.00	207.00	527.00	256.00	318.00	122.00	232.00	258.38
E0	219.33	161.33	251.33	394.33	361.67	282.00	163.00	152.67	248.21
E10	229.00	145.33	242.67	333.33	231.00	266.33	159.00	187.67	224.29
E20	184.67	208.33	168.33	273.00	226.33	162.33	151.67	174.33	193.62
E25	156.00	156.33	157.00	196.67	204.00	141.67	153.67	146.33	163.96
N0	268.33	241.67	199.67	518.33	354.33	260.67	140.00	211.67	274.33
N10	348.00	191.66	196.00	455.67	283.67	216.00	134.67	154.00	247.46
N20	218.67	183.33	145.00	263.33	195.33	200.00	122.67	139.67	183.50
N25	153.00	150.67	143.67	223.00	146.00	143.33	119.67	120.33	149.96
S0	165.67	157.00	312.00	396.33	349.00	283.67	191.67	186.33	255.21
S10	185.67	151.67	215.33	355.67	225.33	230.33	166.33	197.00	215.92
S20	233.33	141.00	162.67	306.67	185.00	198.67	122.00	146.00	186.92
S25	180.67	168.33	134.00	177.33	169.00	174.33	113.67	141.33	157.33
W0	146.67	287.67	332.67	464.33	373.67	282.00	162.33	178.00	278.42
W10	167.67	177.67	189.00	382.67	303.33	225.33	184.67	154.33	223.08
W20	179.33	176.33	152.00	325.67	263.00	191.67	121.00	129.33	192.29
W25	186.00	136.33	205.67	262.33	140.00	142.00	149.67	133.33	169.42
Mean Sq.	43.36	29.10*	45.79	104.80	70.44*	30.16*	7.95	11.58	-

Mean Square values with * are significant at $p < 0.05$

Appendix 4: Concentrations of Iron (Fe) (mg/kg) in Distances within 25m along the Different Gradient Points

Point X Distance	MARCH 2008	MAY 2008	JULY 2008	SEPT. 2008	JAN. 2009	MARCH 2009	MAY 2009	JULY 2009	Mean
C	1255.0	940.0	1030.0	215.0	1255.0	1315.0	975.0	825.0	976.3
Rd	8600.0	8370.0	6260.0	8040.0	7650.0	8640.0	7440.0	8280.0	7910.00
E0	8500.0	7136.7	8550.0	9250.0	8913.3	7780.0	7023.3	7886.7	8130.00
E10	6756.7	7760.0	7403.3	7423.3	9090.0	8936.7	7753.3	7320.0	7805.41
E20	7243.3	8250.0	8006.7	8203.3	7396.7	7930.0	7796.7	7330.0	7769.59
E25	8110.0	7953.3	7223.3	7886.7	8103.3	7683.3	6780.0	7963.3	7712.90
N0	7800.0	7650.0	8300.0	7533.3	8873.3	8680.0	6953.3	6936.7	7840.83
N10	8546.7	8296.7	7750.0	7190.0	9260.0	8840.0	8606.7	8283.3	8346.68
N20	8356.7	7486.7	7196.7	7593.3	7180.0	8456.7	6073.3	7206.7	7443.76
N25	8460.0	7560.0	8140.0	7223.3	7743.3	7603.3	7553.3	6400.0	7585.40
S0	7630.0	7910.0	8843.3	8506.7	7643.3	8220.0	8020.0	8743.3	8189.58
S10	7726.7	7840.0	6780.0	7570.0	7656.7	8056.7	7760.0	6443.3	7479.18
S20	7806.7	8693.3	8500.0	8003.3	7563.3	7403.3	6790.0	7363.3	7765.40
S25	7936.7	7440.0	7943.3	7736.7	7743.3	7663.3	6663.3	6603.3	7466.24
W0	6710.0	7810.0	8533.3	8726.7	9093.3	7990.0	6886.7	7060.0	7851.25
W10	6800.0	7543.3	7366.7	8113.3	7316.7	8336.7	7153.3	7096.7	7465.84

W20	7773.3	7766.7	7630.0	8096.7	8406.7	7436.7	7146.7	7073.3	7666.26
W25	7300.0	7303.3	8056.7	7010.0	8646.7	7443.3	8353.3	6136.7	7531.25
Mean Sq.	532.6	334.0	600.3	438.5	988.4	305.9	1166.4	1033.9	-

Mean Square values with * are significant at p< 0.05

Appendix 5a: Correlation between Pb, Cd and Fe in Ori-Ile waste-dump Soil and surroundings in March 2008

Metals	Pb	Cd	Fe
Pb	1		
Cd	0.9690*	1	
Fe	0.8216*	0.7614*	1

N = 72 (Values with * are significant at P < 0.05)

Appendix 5b: Correlation between Pb, Cd and Fe in Ori-Ile waste-dump and surroundings in May 2008

Metals	**Pb**	**Cd**	**Fe**
Pb	1		
Cd	0.9709*	1	
Fe	0.8382*	0.7816*	1

N = 72 (Values with * are significant at P < 0.05)

Appendix 5c: Correlation between Pb, Cd and Fe in Ori-Ile waste-dump and surroundings in July 2008

Metals	Pb	Cd	Fe
Pb	1		
Cd	0.9029*	1	
Fe	0.8797*	0.7392*	1

N = 72 (Values with * are significant at P < 0.05)

Appendix 5d: Correlation between Pb, Cd and Fe in Ori-Ile waste-dump and surroundings in September 2008

Metals	Pb	Cd	Fe
Pb	1		
Cd	0.9762*	1	
Fe	0.8345*	0.7216*	1

N = 72 (Values with * are significant at P < 0.05)

Appendix 5e: Correlation between Pb, Cd and Fe in Ori-Ile waste-dump and surroundings in Jan 2009

Metals	Pb	Cd	Fe
Pb	1		
Cd	0.9688*	1	
Fe	0.8651*	0.7781*	1

N = 72 (Values with * are significant at P < 0.05)

Appendix 5f: Correlation between Pb, Cd and Fe in Ori-Ile waste-dump and surroundings in March 2009

Metals	Pb	Cd	Fe
Pb	1		
Cd	0.9653*	1	
Fe	0.9290*	0.8408*	1

N = 72 (Values with * are significant at P < 0.05)

Appendix 5g: Correlation between Pb, Cd and Fe in Ori-Ile waste-dump and surroundings in May 2009

Metals	Pb	Cd	Fe
Pb	1		
Cd	0.9220*	1	
Fe	0.8086*	0.8241*	1

N = 72 (Values with * are significant at P < 0.05)

Appendix 5h: Correlation between Pb, Cd and Fe in Ori-Ile waste-dump and surroundings in JULY 2009

Metals	Pb	Cd	Fe
Pb	1		
Cd	0.9770*	1	
Fe	0.8699*	0.8328*	1

N = 72 (Values with * are significant at P < 0.05)

Appendix 5i: Pollution Load index (PLI) of the heavy metals within the soil samples

Soil Sample description	PLI value (Pb)	PLI value (Cd)	PLI value (Fe)
Rd	9.455	15.384	6.312
North	9.258	14.450	6.283
South	9.141	14.221	6.262
East	9.167	14.307	6.299
West	9.233	14.495	6.236

When PLI value is below or close to one, it indicates heavy metal loads at the baseline, while values above one indicate heavy metal accumulation or pollution in soil from the test site.

Appendix 6a: Average Bimonthly Soil Particle Distribution in Waste-Dump and surroundings

Soil content	Rd	North-d	East-d	West-d	South-d	Mean
% sand	64.43 ±14.97	72.87 ±9.64	70.43 ±8.64	73.76 ±7.36	71.08 ±8.11	72.48 ±9.48
% silt	21.06 ±14.46	15.90 ±10.60	17.12 ±8.90	13.33 ±9.03	14.76 ±8.11	14.73 ±9.69
% clay	12.28 ±2.75	12.44 ±2.67	12.72 ±2.71	13.10 ±3.14	13.32 ±4.00	12.61 ±2.70

Appendix 6bi: Other Waste-Dump Soil Parameters

Sample description	Porosity (cm^3/cm^3)	M.C. (g/cm^3)	pH H_2O	pH KCl	H^+ (Cmol/kg)	CEC	Base Sat. (%)
East	0.52±0.11	1.27±0.29	6.23±0.64	5.35±0.66	0.07±0.02	1.81±0.45	95.91±1.98
North	0.51±0.11	1.30±0.29	6.28±0.72	5.38±0.75	0.06±0.03	1.87±0.38	96.24±1.67
West	0.52±0.10	1.27±0.25	6.17±0.60	5.31±0.68	0.07±0.08	1.99±0.42	96.33±1.90
South	0.50±0.11	1.32±0.28	6.14±0.71	5.23±0.71	0.07±0.03	1.83±0.46	95.73±2.39
On-site (R)	0.52±0.11	1.31±0.29	6.00±0.82	5.20±0.66	0.07±0.03	1.79±0.44	95.65±2.44

Appendix 6bii: Other Waste-Dump Soil Parameters

Sample description	O.C. (%)	O.M. (%)	Ca(10^4) (Cmol/kg)	Mg(10^4) (Cmol/kg)	Na(10^4) (Cmol/kg)	K(10^5) (Cmol/kg)	A.V.P(10^2) (ppm)
East	1.31±0.68	2.24±1.17	0.80±0.16	0.53±0.13	0.33±0.12	0.17±0.08	5.95±2.32
North	1.24±0.76	2.13±1.31	0.81±0.15	0.55±0.12	0.33±0.11	0.18±0.08	6.23±3.10
West	1.22±0.82	2.10±1.40	0.82±0.16	0.56±0.13	0.36±0.12	0.19±0.09	5.67±2.52
South	1.21±0.73	2.08±1.26	0.76±0.20	0.53±0.14	0.33±0.13	0.18±0.08	5.53±2.22
On-site (R)	1.02±0.76	1.73±1.34	0.77±0.18	0.51±0.14	0.30±0.13	0.16±0.08	5.90±2.78

Appendix 7a: Concentrations of Lead (Pb) (ppm) in Ori-Ile Groundwater Samples, Control andWHO Standard

Point	March 2008	May 2008	July 2008	Sept 2008	Jan 2009	March 2009	May 2009	July 2009	Overall mean
WHO	0.0100^{b}	0.0100^{b}	0.0100^{ab}	0.0100^{b}	0.0100^{ab}	0.0100^{c}	0.0100^{ab}	0.0100^{ab}	0.0100
NESREA-L	0.0500^{a}	0.0500^{a}	0.0500^{a}	0.0500^{a}	0.0500^{a}	0.0500^{a}	0.0500^{a}	0.0500^{a}	0.0500
Control	0.0000^{b}	0.0000^{c}	0.0000^{b}	0.0000^{b}	0.0000^{b}	0.0000^{d}	0.0000^{ab}	0.0000^{b}	0.0000
East DS	0.0700 ±0.040^{a}	0.0550 ±0.007^{a}	0.1100 ±0.014^{a}	0.0000^{b}	0.0000^{b}	0.0650 ±0.007^{a}	0.0000^{ab}	0.0000^{b}	0.0375±0.009
West DS	0.0450 ±0.007^{a}	0.0100^{b}	0.0300^{ab}	0.0000^{b}	0.0000^{b}	0.0300^{b}	0.0000^{ab}	0.0000^{b}	0.0144±0.001
North DS	0.0000^{b}	0.0000^{c}	0.0755± 0.086^{ab}	0.0150 ±0.017^{b}	0.0250± 0.017^{a}	0.0000^{d}	0.0175± 0.021^{ab}	0.0000^{b}	0.0166±0.018
South DS	0.0000^{b}	0.0000^{c}	0.0100^{ab}	0.0000^{b}	0.0000^{b}	0.0000^{d}	0.0000^{ab}	0.0000^{b}	0.0013
Mean	0.0114	0.0068	0.0285	0.0096	0.0055	0.0095	0.0041	0.0009	0.0095
SD	0.0249	0.0162	0.0507	0.0173	0.0118	0.0201	0.0105	0.0029	0.0193
Mean^{2}	0.0012*	0.0006*	0.0035	0.0006*	0.0002*	0.0009*	0.0001	0.00002*	-

Means with the same letter (for each month) are not significantly different at p< 0.05.

Appendix 7b: Concentrations of Cadmium (Cd) (ppm) in Ori-Ile Groundwater Samples, Control andWHO Standard

Point	March 2008	May 2008	July 2008	Sept 2008	Jan 2009	March 2009	May 2009	July 2009	Over all mean
WHO	0.0030^{ab}	0.0030^{c}	0.0030^{b}	0.0030^{b} ^{c}	0.0030^{a} ^{b}	0.0030^{a} ^{b}	0.0030 ^{b}	0.0030^{c}	0.0030
NESREA-L	0.0100^{a}	0.0100^{a}	0.0100^{a}	0.0100^{a}	0.0100^{a}	0.0100^{a}	0.0100 ^{a}	0.0100^{a}	0.0100
Control	0.0000^{ab}	0.0000^{d}	0.0000^{b}	0.0000^{c}	0.0000^{b}	0.0000^{c}	0.0000 ^{c}	0.0000^{d}	0.0000
East DS	0.0030± 0.004^{ab}	0.0075 ± 0.001^{b}	0.0030^{b}	0.0095 ±0.001^{a} ^{b}	0.0055 ± 0.001^{a}	0.0035± 0.001^{ab}	0.0035 ±0.001 ^{b}	0.0095±0.001^{b}	0.0056±0.001
West DS	0.0055± 0.001^{ab}	0.0140 ± 0.001^{a}	0.0010^{b}	0.0035 ±0.001^{b} ^{c}	0.0000^{b}	0.0025± 0.001^{b}	0.0000 ^{c}	0.0025±0.001^{c}	0.0036±0.001
North DS	0.0068± 0.008^{ab}	0.0000^{d}	0.0030 ± 0.003^{b}	0.0053 ±0.006^{b} ^{c}	0.0023 ± 0.003^{b}	0.0005± 0.001^{c}	0.0018 ±0.002 ^{bc}	0.0125±0.001^{a}	0.0040±0.003
South DS	0.0000^{ab}	0.0000^{d}	0.0020^{b}	0.0000^{c}	0.0005 ± 0.001^{b}	0.0000^{c}	0.0000 ^{c}	0.0000^{d}	0.0003±0.001
MEAN	0.0023	0.0022	0.0031	0.0044	0.0012	0.0009	0.0028	0.0036	0.0026
SD	0.0042	0.0045	0.0046	0.0050	0.0020	0.0014	0.0032	0.0051	0.0038
Mean^{2}	0.000002	0.000045*	0.000045*	0.000047*	0.000007*	0.000004*	0.000022*	0.000061*	-

Means with the same letter (for each month) are not significantly different at p< 0.05.

Appendix 7c: Concentrations of Iron (Fe) (ppm) in Ori-Ile Groundwater Samples, Control and WHO/NESREA Standard

Point	March 2008	May 2008	July 2008	Sept 2008	Jan 2009	March 2009	May 2009	July 2009	Overall mean
WHO	0.3000[a]	0.3000[a]	0.3000[a]	0.3000[a]	0.3000[a]	0.3000[a]	0.3000[a]	0.3000[a]	0.3000
NESREA-L	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Control	0.0000[c]	0.0000[d]	0.0000[c]	0.0000[c]	0.0000[d]	0.0000[d]	0.0000[c]	0.0000[c]	0.0000
East DS	0.0600 ± 0.085[c]	0.0750± 0.007[b]	0.0350± 0.007[bc]	0.0350± 0.007[bc]	0.0350 ± 0.007[cd]	0.0200[cd]	0.0100[c]	0.0000[c]	0.0338 ±0.0141
West DS	0.1250 ± 0.007[b]	0.0400[c]	0.0550± 0.007[b]	0.0600[b]	0.0000[d]	0.0450 ±0.007[bc]	0.0250±0.007[c]	0.0000[c]	0.0438 ±0.0035
North DS	0.0175 ± 0.021[c]	0.0050± 0.010[d]	0.0325± 0.038[bc]	0.0750± 0.035[b]	0.0900 ±0.018[b]	0.0450 ±0.023[bc]	0.0200±0.023[c]	0.0450 ±0.019[b]	0.0413 ±0.0234
South DS	0.0000[c]	0.0000[d]	0.0450± 0.007[bc]	0.0100[c]	0.0400 ±0.057[cd]	0.0000[d]	0.0000[c]	0.0000[c]	0.0119 ±0.008
MEAN	0.0473	0.0395	0.0491	0.0618	0.0573	0.0477	0.0391	0.0355	0.0472
SD	0.0923	0.0875	0.0849	0.0836	0.0870	0.0846	0.0865	0.0877	0.0868
Mean[2]	0.0189 *	0.0178*	0.0163*	0.0159*	0.0172 *	0.0165 *	0.0173*	0.0178 *	-

Means with the same letter (for each month) are not significantly different at $p< 0.05$.

Appendix 7d: Correlations between Pb, Cd and Fe in the well water samples of Ori-Ile waste-dump site and control in March 2008

March 2008	Pb	Cd	Fe
Pb	1.0000		
Cd	0.1009	1.0000	
Fe	0.2126	0.1874	1.0000

Values with * are significant at P < 0.05 N = 64

Appendix 7e: Correlations between Pb, Cd and Fe in the well water samples of Ori-Ile waste-dump site and control in May 2008

May 2008	**Pb**	**Cd**	**Fe**
Pb	1.0000		
Cd	0.5539*	1.0000	
Fe	0.3057	0.2572	1.0000

Values with * are significant at P < 0.05, N = 64

Appendix 7f: Correlations between Pb, Cd and Fe in the well water samples of Ori-Ile waste-dump site and control in July 2008

July 2008	Pb	Cd	Fe
Pb	1.0000		
Cd	0.1396	1.0000	
Fe	0.0760	-0.0022	1.0000

Values with * are significant at $P < 0.05$, $N = 64$

Appendix 7g: Correlations between Pb, Cd and Fe in the well water samples of Ori-Ile waste-dump site and control in September 2008

September 2008	Pb	Cd	Fe
Pb	1.0000		
Cd	0.4824*	1.0000	
Fe	0.2735	0.1577	1.0000

Values with * are significant at $P < 0.05$, $N = 64$

Appendix 7h: Correlations between Pb, Cd and Fe in the well water samples of Ori-Ile waste-dump site and control in January 2009

January 2009	Pb	Cd	Fe
Pb	1.0000		
Cd	0.0054	1.0000	
Fe	0.3339	0.4424*	1.0000

Values with * are significant at $P < 0.05$, $N = 64$

Appendix 7i: Correlations between Pb, Cd and Fe in the well water samples of Ori-Ile waste-dump site and control in March 2009

March 2009	Pb	Cd	Fe
Pb	1.0000		
Cd	0.8065*	1.0000	
Fe	0.0357	0.5498*	1.0000

Values with * are significant at $P < 0.05$, $N = 64$

Appendix 7j: Correlations between Pb, Cd and Fe in the well water samples of Ori-Ile waste-dump site and control in May 2009

May 2009	**Pb**	**Cd**	**Fe**
Pb	1.0000		
Cd	0.0856	1.0000	
Fe	0.2759	-0.0405	1.0000

Values with * are significant at P < 0.05, N = 64

Appendix 7k: Correlations between Pb, Cd and Fe in the well water samples of Ori-Ile waste-dump site and control in July 2009

July 2009	**Pb**	**Cd**	**Fe**
Pb	1.0000		
Cd	-0.0402	1.0000	
Fe	0.9763*	0.1276	1.0000

Values with * are significant at $P < 0.05$; $N = 64$

Appendix 8a: Mean Concentration of Lead (Pb) in the Ori-Ile Surface Water Samples

Distance	MARCH 2008	MAY 2008	JULY 2008	SEPT 2008	JAN 2009	MARCH 2009	MAY 2009	JULY 2009	Overall Mean
Downstream	0^{a}	0^{a}	0^{a}	0^{a}	0^{a}	0^{a}	2.1500 ± 0.07^{a}	0.0550 ± 0.007^{a}	0.275 ± 0.096
Midstream	0^{a}	0^{a}	0^{a}	0^{a}	0^{a}	0^{a}	0.1550 ± 0.007^{b}	0.0350 ± 0.007^{b}	0.0238 ± 0.0018
Upstream	0^{a}	0^{a}	0^{a}	0^{a}	0^{a}	0^{a}	0^{C}	0^{C}	0.0000
WHO-L	0.0100^{b}	0.0100^{b}	0.0100^{ab}	0.0100^{b}	0.0100^{ab}	0.0100^{c}	0.0100^{a}	0.0100^{a}	0.0100
NESREA-L	0.0500	0.0500	0.0500	0.0500	0.0500	0.0500	0.0500	0.0500	0.0500
Control	0.0000^{a}	0.0000^{a}	0.0000^{a}	0.0000^{a}	0.0000^{a}	0.0000^{a}	0.0000^{C}	0.0000^{C}	0.0000
MEAN	0	0	0	0	0	0	0.7683	0.0300	0.0998
SD	0	0	0	0	0	0	1.0729	0.0253	0.1373
Mean[2]	0.0000^{nd}	0.0000^{nd}	0.0000^{nd}	0.0000^{nd}	0.0000^{nd}	0.0000^{nd}	2.8755*	0.0016*	-

Means with the same letter (for each month) are not significantly different at $p< 0.05$.

Appendix 8b: Mean Concentration of Cadmium (Cd) in the Ori-Ile Surface Water Samples

Distance	MARCH 2008	MAY 2008	JULY 2008	SEPT 2008	JAN 2009	MARCH 2009	MAY 2009	JULY 2009	Overall Mean
Downstream	0^{b}	0^{b}	0.0075 ± 0.002^{a}	0.0100^{a}	0.0065 ± 0.0007^{a}	0^{b}	0.1710 ± 0.004^{a}	0.0065 ± 0.0007^{a}	0.0252±0.0009
Midstream	0^{b}	0^{b}	0^{b}	0.0070 ± 0.001^{b}	0.0055 ± 0.0007^{a}	0^{b}	0^{c}	0.0050 ± 0.001^{a}	0.0022±0.0003
Upstream	0^{b}	0^{b}	0^{b}	0^{c}	0^{b}	0^{b}	0^{c}	0^{b}	0.0000
WHO-L	0.0030^{a}	0.0030^{a}	0.0030^{ab}	0.0030^{ab}	0.0030^{ab}	0.0030^{a}	0.0030^{b}	0.0030^{ab}	0.0030
NESREA-L	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100
Control	0.0000^{b}	0.0000^{b}	0.0000^{b}	0.0000^{c}	0.0000^{b}	0.0000^{b}	0.0000^{c}	0.0000^{b}	0.0000
MEAN	0	0	0.0025	0.0057	0.0040	0	0.0570	0.0038	0.0091
SD	0	0	0.0040	0.0046	0.0032	0	0.0883	0.0031	0.0129
Mean²	0.0000^{nd}	0.0000^{nd}	0.000038*	0.000053*	0.000025*	0.0000^{nd}	0.0195*	0.000023*	-

Means with the same letter (for each month) are not significantly different at $p< 0.05$.

Appendix 8c: Mean Concentration of Iron (Fe) in the Ori-Ile Stream Water Samples

Distance	MARCH 2008	MAY 2008	JULY 2008	SEPT 2008	JAN 2009	MARCH 2009	MAY 2009	JULY 2009	Overall mean
Downstream	0.100±0.014^{b}	12.900±0.07^{a}	0.450±0.007^{b}	0.300^{b}	0.750±0.007^{b}	0.400±0.014^{b}	0.650±0.007^{b}	0.750±0.007^{b}	2.0375±0.0158
Midstream	0.0100±0.014^{b}	0^{b}	0.350±0.007^{b}	0.100^{c}	0.450±0.007^{c}	0.0200^{bc}	0.550±0.007^{b}	0.350±0.007^{c}	0.2625±0.0053
Upstream	0^{b}	0^{b}	0.250±0.007^{b}	0^{d}	0^{d}	0^{c}	0.550±0.007^{b}	0.200^{c}	0.125±0.0018
WHO	0.3000^{a}	0.3000^{ab}	0.3000^{a}	0.3000^{a}	0.3000^{a}	0.3000^{a}	0.3000^{a}	0.3000^{a}	0.3
NESREA-L	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Control	0.0163^{b}	0.0163^{b}	0.0163^{bc}	0.0163^{bc}	0.0163^{cd}	0.0163^{bc}	0.0163^{c}	0.0163^{c}	0.0163
MEAN	0.0067	0.4300	0.0350	0.0133	0.0400	0.0200	0.0583	0.0433	0.080825
SD	0.0103	0.6669	0.0105	0.0137	0.0341	0.0190	0.0075	0.0258	0.098475
Mean^{2}	0.000067	1.1094*	0.0002	0.00047*	0.0029*	0.0008*	0.000067	0.0016*	-

Means with the same letter (for each month) are not significantly different at $p< 0.05$.

Appendix 8d: Correlations between Pb, Cd and Fe in Stream Water Samples in March 2008

March 2008	**Pb**	**Cd**	**Fe**
Pb	-		
Cd	-	-	
Fe	-	-	1.0000

N = 24 Values with * are significant at P < 0.05

Appendix 8e: Correlations between Pb, Cd and Fe in Stream Water Samples in May 2008

May 2008	**Pb**	**Cd**	**Fe**
Pb	-		
Cd	-	-	
Fe	-	-	1.0000

N = 24 Values with * are significant at P < 0.05

Appendix 8f: Correlations between Pb, Cd and Fe in Stream Water Samples in July 2008

July 2008	**Pb**	**Cd**	**Fe**
Pb	-		
Cd	-	1.0000	
Fe	-	-0.7891	1.0000

N = 24 Values with * are significant at P < 0.05

Appendix 8g: Correlations between Pb, Cd and Fe in Stream Water Samples in September 2008

Sept 2008	**Pb**	**Cd**	**Fe**
Pb	-		
Cd	-	1.0000	
Fe	-	0.5266	1.0000

N = 24 Values with * are significant at P < 0.05

Appendix 8h: Correlations between Pb, Cd and Fe in Stream Water Samples in January 2009

Jan 2009	Pb	Cd	Fe
Pb	-		
Cd	-	1.0000	
Fe	-	0.8171*	1.0000

N = 24 Values with * are significant at P < 0.05

Appendix 8i: Correlations between Pb, Cd and Fe in Stream Water Samples in March 2009

March 2009	**Pb**	**Cd**	**Fe**
Pb	-		
Cd	-	-	
Fe	-	-	1.0000

N = 24 Values with * are significant at P < 0.05

Appendix 8j: Correlations between Pb, Cd and Fe in Stream Water Samples in May 2009

May 2009	**Pb**	**Cd**	**Fe**
Pb	1.0000		
Cd	0.9979*	1.0000	
Fe	0.6954	0.6949	1.0000

N = 24 Values with * are significant at P < 0.05

Appendix 8k: Correlations between Pb, Cd and Fe in Stream Water Samples in July 2009

July 2009	**Pb**	**Cd**	**Fe**
Pb	1.0000		
Cd	0.7842	1.0000	
Fe	0.3980	0.7766	1.0000

N = 24 Values with * are significant at P < 0.05

Appendix 9a: Mean Concentration of the Selected Essential Nutrients within the Cultivated Maize Plant (25m Distance from the Waste-dump) and Control

	Na	K	Ca	Mg	P	N
Leaf	5.179^{b}	6.434^{c}	2.300^{d}	0.000^{e}	0.499^{b}	0.000^{e}
Cob	3.600^{e}	6.275^{d}	1.100^{e}	0.000^{e}	0.270^{f}	0.000^{e}
Stem	0.900^{g}	2.900^{h}	0.100^{f}	0.000^{e}	0.080^{h}	0.000^{e}
Root	1.100^{f}	3.100^{g}	0.300^{g}	0.000^{e}	0.050^{g}	0.000^{e}
Control leaf	7.900^{a}	11.600^{a}	7.041^{a}	7.340^{a}	0.580^{a}	0.690^{a}
Control cob	5.050^{b}	6.900^{b}	6.848^{b}	7.199^{b}	0.484^{c}	0.672^{b}
Control root	4.605^{d}	5.655^{f}	6.368^{c}	6.389^{d}	0.399^{e}	0.644^{c}
Control stem	4.897^{c}	6.032^{e}	6.756^{b}	6.914^{c}	0.452^{d}	0.589^{d}
Mean	4.154	6.112	3.852	3.480	3.516	3.245
SD	0.2217	0.2594	0.3068	0.3604	0.1915	0.3363
Mean^{2} (Part)	0.1053*	0.1442*	0.2017*	0.2784*	0.0785*	0.2423*

Means with the same letter (for each month) are not significantly different at $p< 0.05$.

Mean^{2} values with * are significant at $p< 0.05$

Appendix 9b: Mean Concentration of the Selected Non-Essential Metals within the Cultivated Maize Plant (25m Distance from the Waste-dump) and Control

	Pb	**Cd**	**Fe**
Leaf	39.0300[b]	2.6460[b]	90.2400[c]
Cob	37.4200[c]	2.5000[c]	56.7000[e]
Stem	36.4200[d]	2.4100[d]	35.2000[f]
Root	40.9500[a]	2.8420[a]	26.7000[g]
Control leaf	0.1300[e]	0.0000[e]	103.2000[b]
Control cob	0.0000[h]	0.0000[e]	83.8000[d]
Control root	0.1100[f]	0.0000[e]	101.8900[b]
Control stem	0.0600[g]	0.0000[e]	117.3900[a]
Mean	22.9800	0.1300	76.8900
SD	16.4500	0.1348	32.3500
Mean^2(Part)	5.8000*	0.3890*	22.4200*

Means with the same letter (for each month) are not significantly different at $p< 0.05$.

Mean^2 values with * are significant at $p< 0.05$

Appendix 9c: Correlations between Heavy Metals (Pb, Cd) and other essential nutrients in the maize samples

	Na	K	Ca	Mg	P	N	Pb	Cd	Cu	Fe
Na	1.0000									
K	0.9267*	1.0000								
Ca	0.5485*	0.2037	1.0000							
Mg	0.3671	0.0009	0.9784*	1.0000						
P	0.9644*	0.8078*	0.7356*	0.5843*	1.0000					
N	0.3675	0.0017	0.9782*	0.9999*	0.5852*	1.0000				
Pb	0.4192	0.0499	0.9582*	0.9661*	0.6047*	0.9651*	1.0000			
Cd	0.3582	-0.0088	0.9700*	0.9896*	0.5657*	0.9885*	0.9747*	1.0000		
Cu	0.4879	0.1335	0.9937*	0.9848*	0.6793*	0.9840*	0.9730*	0.9890*	1.0000	
Fe	0.8494*	0.6357*	0.7886*	0.6624*	0.8857*	0.6596*	0.7344*	0.6971*	0.7761*	1.0000

Values with * are significant at $p < 0.05$

Appendix 9d: Pollution Load Index (PLI) of the Heavy Metals within the Cultivated Maize

Maize Parts	PLI value (Pb)	PLI value (Cd)	PLI value (Fe)
Grain	0.668	1.776	0.530
stem	0.663	1.760	0.523
Root	0.688	1.830	0.545
Leaf	0.677	1.801	0.537

Appendix 10: Average Weight, Shank Length, Wing Length and Girth of Broilers from Day Old to Eight (8) Weeks

Bird Description	Bird Weight	Shank Length	Wing Length	Bird Girth
Day old (N=35)	42.97±3.84	n.t.	n.t.	n.t.
2weeks old (N=35)	94.77±12.10	1.95±0.08	10.81±0.48	7.65±0.32
Exptal. (4wks N=15)	137.87±20.21	2.31±0.09	12.16±0.85	9.34±0.38
Control (4wks N=15)	155.33±27.85	2.31±0.08	12.39±0.81	9.46±0.42
Exptal. (6wks N=10)	273.00±35.51	2.51±0.07	13.44±0.69	11.02±0.26
Control (6wks N=10)	342.60±41.55	2.50±0.06	13.56±0.46	11.10±0.39
Exptal. (8wks N=5)	480.40±62.00	3.34±0.25	14.74±0.43	17.10±0.54
Control (8wks N=5)	510.20±81.05	3.42±0.08	15.14±0.40	17.94±0.99

nt = not taken due to age constraint

Appendix 11a: Mean Concentrations of Pb in Skin, Liver, Femur and Plasma of 4-8weeks Old Broiler Chicks

Sample	Skin Pb (4wks)	Skin Pb (6wks)	Skin Pb (8wks)	Liver Pb (4wks)	Liver Pb (6wks)	Liver Pb (8wks)	Femur Pb (4wks)	Femur Pb (6wks)	Femur Pb (8wks)
Expt. (ppm)	0.0128	0.0092	0.0058	0.0136	0.0060	0.0056	0.0086	0.0084	0.0046
Control (ppm)	0.0009	0.0006	0.0005	0.0016	0.0004	0.0006	0.0007	0.0006	0.0005
S.D.$^{Expt.}$	0.0023	0.0023	0.0015	0.0017	0.0020	0.0009	0.0005	0.0005	0.0005
S.D.^{Ctrl}	0.0001	0.0001	0.0001	0.0001	0.0001	0.0003	0.0001	0.0001	0.0002
t-value	3.5590*	2.9970*	1.0890	3.3130*	2.8040*	-0.2740	4.0000*	4.7070*	0.0000

Plasma Pb (4wks)	Plasma Pb (6wks)	Plasma Pb (8wks)
0.0072	0.0032	0.0032
0.0005	0.0002	0.0001
0.0011	0.0004	0.0016
0.0001	0.0001	0.0001
3.7730*	2.5300*	2.3240*

N = 5; t-value with* is significant at P< 0.05

Appendix 11b: Mean Concentrations of Cd in Skin, Liver, Femur and Plasma of 4-8weeks Old Broiler Chicks

Sample	Skin Cd (4wks)	Skin Cd (6wks)	Skin Cd (8wks)	Liver Cd (4wks)	Liver Cd (6wks)	Liver Cd (8wks)	Femur Cd (4wks)	Femur Cd (6wks)	Femur Cd (8wks)
Expt. (ppm)	0.0110	0.0042	0.0088	0.0110	0.0022	0.0074	0.0062	0.0050	0.0050
Control (ppm)	0.0008	0.0004	0.0004	0.0012	0.0001	0.0006	0.0005	0.0003	0.0003
S.D.$^{Expt.}$	0.0020	0.0013	0.0022	0.0034	0.0013	0.0005	0.0016	0.0007	0.0007
S.D.^{Ctrl}	0.0002	0.0001	0.0001	0.0003	0.0001	0.0001	0.0002	0.0000	0.0001
t-value	2.1230	0.2500	4.8110*	0.3980	1.4430	3.0870*	0.7630	5.8800*	4.0000*

Plasma Cd (4wks)	Plasma Cd (6wks)	Plasma Cd (8wks)
0.0036	0.0014	0.0042
0.0002	0.0001	0.0003
0.0019	0.0009	0.0008
0.0001	0.0000	0.0000
1.4760	1.0000	3.2070*

N = 5

t-value with* is significant at P< 0.05

Appendix 11c: Mean Concentrations of Fe in Skin, Liver, Femur and Plasma of 4-8weeks Old Broiler Chicks

Sample	Skin Fe (4wks)	Skin Fe (6wks)	Skin Fe (8wks)	Liver Fe (4wks)	Liver Fe (6wks)	Liver Fe (8wks)	Femur Fe (4wks)	Femur Fe (6wks)	Femur Fe (8wks)
Expt. (ppm)	145.4026	133.6300	86.1292	302.0070	281.4954	300.7590	122.5098	101.0642	155.4140
Control (ppm)	152.4848	167.0890	88.1230	304.7774	291.7246	301.5208	128.4566	122.6196	155.9890
S.D.$^{Expt.}$	6.7872	8.4735	3.7054	28.0225	15.5327	23.0803	11.2748	7.1725	16.1975
S.D.^{Ctrl}	12.9433	64.3805	6.0912	30.7782	16.4760	11.2425	11.8363	23.7921	11.7320
t-value	1.0840	-1.1520	0.6250	-0.1490	1.0100	-0.0600	-0.8130	-1.9400	-0.0640

Plasma Fe (4wks)	Plasma Fe (6wks)	Plasma Fe (8wks)
137.5656	133.5894	175.7858
140.9444	135.4772	177.9554
13.7419	5.4447	5.2186
8.9344	14.1722	5.8996
-0.4610	-0.2780	-0.6160

N = 5 t-value with* is significant at P< 0.05

Appendix 11d: Mean Concentrations of Pb in Liver, Skin, Plasma and Femur of Broiler Chicks (4-8weeks)

PART	Pb (4 wks)	Pb (6 wks)	Pb (8 wks)
Liver (ppm)	0.0121^{a}±0.002	0.0047^{b}±0.002	0.0058^{a}±0.002
Skin (ppm)	0.0109^{a}±0.003	0.0076^{a}±0.002	0.0054^{a}±0.001
Plasma (ppm)	0.0061^{c}±0.001	0.0028^{c}±0.001	0.0023^{b}±0.001
Femur (ppm)	0.0078^{b}±0.001	0.0072^{a}±0.001	0.0046^{a}±0.001
MEAN	0.0092	0.0056	0.0045
SD	0.0030	0.0026	0.0020
Mean^{2}	0.00008*	0.00005*	0.00002*

Means with the same letter (for each month) are not significantly different at p< 0.05.

Value with* is significant at P< 0.05

Appendix 11e: Mean Overall Concentrations of Cd in Liver, Skin, Plasma and Femur of Broiler Chicks (4-8weeks)

PART	Cd (4 wks)	Cd (6 wks)	Cd (8 wks)
Liver (ppm)	0.0106^{a}±0.003	0.0017^{b}±0.001	0.0068^{a}±0.001
Skin (ppm)	0.0096^{a}±0.002	0.0041^{a}±0.001	0.0063^{a}±0.003
Plasma (ppm)	0.0029^{c}±0.002	0.0012^{b}±0.001	0.0036^{b}±0.001
Femur (ppm)	0.0058^{b}±0.002	0.0039^{a}±0.001	0.0042^{b}±0.001
MEAN	0.0072	0.0027	0.0052
SD	0.0038	0.0017	0.0022
Mean^{2}	0.00013*	0.00002*	0.00002

Means with the same letter (for each month) are not significantly different at p< 0.05.

Value with* is significant at P< 0.05

Appendix 11f: Mean Overall Concentrations of Fe in Liver, Skin, Plasma and Femur of Broiler Chicks (4-8weeks)

PART	Fe (4 wks)	Fe (6 wks)	Fe (8 wks)
Liver (ppm)	303.3920^{a}±27.788	286.6100^{a}±16..029	301.0980^{a}±17.717
Skin (ppm)	148.9440^{b}±10.434	150.3600^{b}±46.744	87.1260^{d}±4.868
Plasma (ppm)	139.2550^{bc}±11.071	134.5333^{bc}±10.170	176.8710^{b}±5.374
Femur (ppm)	125.4830^{c}±11.340	111.8419^{c}±20.088	155.7020^{c}±13.337
MEAN	179.2685	170.8362	177.0990
SD	74.8318	73.8591	77.5439
Mean^{2}	69400.75*	62070.32*	74637.02*

Means with the same letter (for each month) are not significantly different at p< 0.05.

Value with* is significant at P< 0.05

Appendix 11g: Correlation between the different metals in broilers from 4weeks to 8weeks (N = 40)

	Fe (4 wks)	Fe (6 wks)	Fe (8 wks)	Pb (4 wks)	Pb (6 wks)	Pb (8 wks)	Cd (4 wks)	Cd (6 wks)	Cd (8 wks)
Fe (4 wks)	1.0000								
Fe (6 wks)	0.5587 *	1.0000							
Fe (8 wks)	0.5065 *	0.8112 *	1.0000						
Pb (4 wks)	0.9005 *	0.5358 *	0.5351 *	1.0000					
Pb (6 wks)	-0.1995	0.5746 *	0.4755 *	0.2339	1.0000				
Pb (8 wks)	-0.3668 *	0.2960	0.1952	-0.4104 *	0.8156 *	1.0000			
Cd (4 wks)	0.8263 *	0.2685	0.2132	0.7423 *	-0.3823 *	-0.5144 *	1.0000		
Cd (6 wks)	0.3368 *	0.6706 *	0.6078 *	0.3126 *	0.4500 *	0.2464	0.1023	1.0000	
Cd(8 wks)	0.4454 *	0.8934 *	0.7174 *	0.3675 *	0.5848 *	0.2511	0.1532	0.5638 *	1.0000

Appendix 11h: Pollution Load Index of the Heavy metals within the Broiler Parts

Broiler Chicks Parts	PLI value (Pb)	PLI value (Cd)	PLI value (Fe)
Skin	0.360	0.210	4.241
Liver	0.382	0.195	6.277
Femur	0.343	0.190	4.962

Plasma	0.324	0.171	5.281

When PLI value is below or close to one, it indicates heavy metal loads at the baseline, while values above one indicate heavy metal accumulation or pollution in chick's part.

Appendix 12a: Mean concentrations of Pb in Different Organs of Local Chicks

Sample	Skin Pb	Liver Pb	Femur Pb	Plasma Pb	Heart Pb	Brain Pb	Kidney Pb	Gizzard Pb
Expt. (ppm)	0.0580	0.0680	0.0500	0.0400	0.0500	0.0400	0.0500	0.0400
Control (ppm)	0.0055	0.0065	0.0048	0.0035	0.0045	0.0020	0.0045	0.0030
S.D.$^{Expt.}$	0.0100	0.0150	0.0000	0.0140	0.0080	0.0180	0.0180	0.0140
S.D.^{Ctrl}	0.0007	0.0007	0.0005	0.0013	0.0007	0.0000	0.0007	0.0008
t-value	0.3200	0.2140	-0.6670	-0.4360	0.7300	1.4610	0.3560	-1.1550

N = 5

t-value with* is significant at P< 0.05

Appendix 12b: Mean concentrations of Cd in Different Organs of Local Ikumapaiyi Chicks and control

Sample	Skin Cd	Liver Cd	Femur Cd	Plasma Cd	Heart Cd	Brain Cd	Kidney Cd	Gizzard Cd
Expt. (ppm)	0.0125	0.0088	0.0083	0.0055	0.0060	0.0070	0.0078	0.0053
Control (ppm)	0.0025	0.0050	0.0020	0.0015	0.0020	0.0030	0.0050	0.0025
S.D.$^{Expt.}$	0.0024	0.0005	0.0010	0.0006	0.0028	0.0022	0.0010	0.0005
S.D.^{Ctrl}	0.0007	0.0000	0.0000	0.0007	0.0000	0.0014	0.0014	0.0021
t-value	5.5210	10.0000	8.7040	7.5420	1.8860	2.3090	2.9140*	2.7720*

N = 4

t-value with* is significant at P< 0.05

Appendix 12c: Mean concentrations of Fe in Different Organs of Local Chicks

Sample	Skin Fe	Liver Fe	Femur Fe	Plasma Fe	Heart Fe	Brain Fe	Kidney Fe	Gizzard Fe
Expt. (ppm)	91.9398	298.0015	147.2110	177.4660	212.1680	186.6603	175.0135	112.3748
Control (ppm)	93.6610	311.1060	161.3065	178.2538	214.4685	193.9280	179.1150	129.6755
S.D.$^{Expt.}$	0.9297	8.4825	7.0711	8.3495	4.3091	18.8447	7.2231	9.4264
S.D.^{Ctrl}	8.4146	5.7912	2.7179	9.6679	4.7833	11.0181	2.4977	0.0502
t-value	-0.4640	-1.9160	3.8320	0.0970	0.5690	-0.4870	1.1250	-2.4470

N = 4

t-value with* is significant at P< 0.05

Appendix 12d: Average Concentration of Pb, Cd and Fe in Local Chicks Organs (Dumpsite & Control)

PART	Fe	Pb	Cd
Liver (ppm)	302.3700^{a}±9.7813	0.0067^{a}±0.0012	0.0075^{ab}±0.0020
Heart (ppm)	213.7020^{b}±4.33420	0.0048^{bc}±0.0008	0.0047^{b}±0.0030
Brain (ppm)	189.0830^{c}±15.8568	0.0033^{c}±0.0018	0.0057^{ab}±0.0027
Plasma (ppm)	177.9910^{d}±8.3779	0.0037^{c}±0.0012	0.0042^{b}±0.0021
Kidney (ppm)	177.7480^{d}±4.3201	0.0048^{bc}±0.0015	0.0068^{ab}±0.0017
Femur (ppm)	156.6080^{e}±8.2106	0.0048^{bc}±0.0004	0.0062^{ab}±0.0033
Gizzard (ppm)	118.1420^{f}±11.5383	0.0033^{c}±0.0010	0.0043^{b}±0.0018
Skin (ppm)	92.5140^{g}±3.9331	0.0057^{ab}±0.0008	0.0092^{a}±0.0055
MEAN	178.5195	0.0046	0.0061
SD	60.6042	0.0015	0.0032
Mean^{2}	24181.49*	0.00001*	0.00002

Means with the same letter (for each column) are not significantly different at $p< 0.05$.

Appendix 12e: Correlation between Concentration of Pb, Cd and Fe in Local Chicks Organs (Dumpsite & Control)

	Fe (ppm)	**Pb (ppm)**	**Cd (ppm)**
Fe (ppm)	1.0000		
Pb (ppm)	0.3047*	1.0000	
Cd (ppm)	0.0315	0.3746*	1.0000

N = 48