LEAD AND CADMIUM CONCENTRATION IM MEAT OBTAINED FROM RUMINANTS SLAUGHTERED IN GUSAU, ZAMFARA STATE, NIGERIA AND RISK ASSESMENT FOR THEIR CONSUMPTION

BY

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AUGUST, 2015

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Contamination of food by heavy metals has made dietary intake one of the major routes of these harmful elements to human beings. This work was designed to determine the levels of lead, and cadmium concentrations in beef, mutton and camel meat and to assess the risk for their consumption in Gusau, Zamfara State Nigeria. Also a survey on public awareness of heavy metal poisoning in Gusau, was carried out. A total of 300 samples of beef, mutton and camel meat were purchased from different retail points in Gusau, transported to the Food Science Research Laboratory in Ahmadu Bello University, Zaria. The meat samples were dried at 160^{o} C for two hours, crushed into fine powder, then 10 g of the fine powdered sample was weighed into porcelain crucible which was ignited in a muffle furnace at 800^{o} C for six to eight hours and allowed to cool in desiccators, 0.1 gram weight of the ash was placed inside a conical flask, a mixture of nitric, perchloric and sulphuric acid was added and heated on sand bath, for digestion, until a clear liquid solution was formed. The solution was filtered using Whatman 42 filter paper and the volume was made up to 25 cm^3 with de-ionized water. The solutions were passed through for atomic absorption spectrometry analyses. The highest concentration of lead (mg/kg), was from camel meat (98.37 ±27.89 mg/kg) followed by beef (93.53± 29.17 mg/kg) and the least was mutton (71.76 ± 43.23 mg/kg).The highest concentration of cadmium (mg/kg), was from beef (21.43 ± 7.96 mg/kg) followed by camel meat of (18.30 ± 5.76 mg/kg) and the least was mutton (5.88± 1.57 mg/kg). Daily intakes (DI) were calculated based on estimates of average daily meat intake, bodyweight and concentrations of either lead or cadmium in the test meats. Therefore DI for lead show that children had a higher daily intake of lead with camel meat contributing the highest (231.19 μg) followed by beef (219.79 μg) and the least was mutton (175.81μg), whereas adults had lower daily intakes of lead with camel meat contributing the highest (96.97 μg) followed by beef at (92.19 μg), and the least was mutton at (70.73 μg).

Children also had a higher daily intake of cadmium with beef contributing the highest (50.36 μg), followed by camel meat (50.36 μg), and the least being mutton (13.82 μg), whereas adults had lower daily intakes of cadmium with beef contributing the highest at (21.12 μg) followed by camel meat at (18.04 μg) and the least being mutton (6.79 μg). The estimated daily dietary intake (EDI) of lead and cadmium for children and adults in μ/kg/bw/day showed that camel meat contributed a slightly higher estimate of the combined metals for children at 274.21 μg/day above beef at 260.15 μg/day, and mutton contributing 189.69 μg/day being the lowest, whereas for adults, camel meat and beef contributed the same at 114.31 μg/day and 114.01 μg/day and the least was mutton 76.52 μg/day respectively. Hazard Risk Index (HRI) from consumption of the various meat showed that the risk for children's' consumption of lead and cadmium in beef is at 0.12 and 5, mutton at 0.12 and 1.3 and camel meat at 0.13 and 4.3 whereas the risk for adults' consumption of beef was at 0.05 and 2.1, mutton at 0.04 and 0.57 and camel meat at 0.05 and 1.8 respectively. The study also showed some level of awareness of lead poisoning among the respondents in Gusau with increasing awareness of the risks posed by domestic exposure to lead, particularly to children. This study has established that there are high levels of lead and cadmium concentrations in beef, mutton, and camel meat sold and consumed in Gusau, Zamfara State, Nigeria above the guideline values established by different food regulatory agencies. This is of public health significance.

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LIST OF ABREVIATIONS

ATSDR	Agency for Toxic Substances & Disease Registry
AOAC	Association of Official Analytical Chemistry
APVMA	Australian Pesticides & Veterinary Medicine Authority
AZNFA	Australia and New Zealand Food Authority
CSEM	Case Studies in Environmental Medicine
DIM	Daily Intake of Metal
EC	European Commission
EDIM	Estimated Daily Intake of Metal
EFSA	European Food Safety Authority
FAO	Food & Agriculture Organization
FDA	Food & Drug Administration
HRI	Hazard Risk Index
1ARC	International Agency for Research on Cancer
IPCS	International Program on Chemical Safety
JECFA	Joint FAO/WHO Expert Committee on Food Additives
MSF	Medicines' Sans Frontiers'
OCHA	United Nations Office for the Coordination of Humanitarian Affairs Environment Unit
PTWI	Provisional Tolerable Weekly Intake
NIOSHA	United States National Institute for Occupational Safety and Health
RDI	Recommended Daily Intake
RfD	Oral Reference Dose
TDI	Tolerable Daily Intake
THQ	Total Hazard Quotient
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CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Heavy metals are metals or metalloids with high relative density of 5.0 or higher, often toxic to organisms (Hawkes, 1997; Dufus, 2002). Heavy metals received attention as environmental contaminants, potential toxicological hazards, economic, social and political issues (Bennet, 2003; Ezemonye and Enuneku, 2005).

Pollution with heavy metals is considered as one of the most serious problems as these metals cannot be degraded and thus stay permanently in the environment (Baykov *et al*., 1996), thereby causing devastating effects on the ecological balance of the recipient environment and the diversity of other organisms (Vinodhini and Narayanan, 2009). Important among these metals are arsenic (Ar), cadmium (Cd), chromium (Cr), lead (Pb) and mercury (Hg) (Barry *et al.*, 2000). Lead and cadmium are of significant public health importance in Nigeria as environmental contaminants of food which have deleterious cumulative effect on human health (Soad and Said, 2013; Orisakwe, 2014).

Lead (Pb), in comparison to the two most abundant metals in the earth crust, aluminum and iron, is a relatively common metal at about 15–20 mg/kg (Polyanski, 1986). The environmental deposits of lead have increased over the past three centuries due to human activities. Human exposure to lead is common due to its many uses, because of its exceptional properties in industries (Bennet, 2003; Vinodhini and Narayanan, 2009) and its distribution in all phases of the environment and biological systems. Its sources include a wide variety of minerals, mine and metal smelters. It is used in construction, ceramics, ammunition, pigments and petrol additives,

in fishing lures, cables, sail boat keels, cars, batteries/accumulators, plastics, paint and sand blasting (Enukeku, 2010). Lead does not have detectable biological roles. On the contrary, many investigators have reported its detrimental effects on biochemical, behavioral and physiological dysfunctions in animals and humans (Ruff *et al*., 1996). Its patho-physiology involves entry into mitochondria, inducing swelling and distortion of mitochondrial cristae, uncoupling energy metabolism, and inhibition of cellular respiration and alteration of calcium kinetics. Lead is reported to induce apoptosis in a number of experimental systems (Iavocoli *et al*., 2001; Gulati *et al*., 2010). The biochemical changes in laboratory animals exposed to environmental chemicals/xenobiotics is an important tool in the overall assessment of the risk and hazards to humans or animal exposure (Krishna and Ramachandran, 2009). Sub-lethal effects are biochemical in origin because most toxicants exert their effects by reacting with enzymes or metabolites and other functional cell components. The end result is irreversible and detrimental disturbances of integrated functions in man and animal such as behavior, growth, reproduction and survival (Abou *et al*., 2005).

Cadmium (Cd) is an environmental contaminant among the most toxic of heavy metals commonly found (Elinder, 1985). Due to its low permissible exposure limit, overexposures may occur even in situations where trace quantities of cadmium are found (Syers *et al*., 1986). Industrial limits on cadmium exposure have been reduced in most industrialized nations and many policy makers agree on the need to reduce exposure further due to buildup of cadmium levels in water, air, and soil which has been on the increase in recent years (Taylor, 1997). Cadmium is primarily found in zinc-containing ores, but it may also be found in lead and copper ores (Microsoft Encarta, 2009). Other sources include industrial and agricultural chemicals. Phosphate in fertilizers contain cadmium in amounts of up to 100 mg/kg (Syers *et al*., 1986)

which can lead to an increase in the concentration of cadmium in soil. Contaminated food is another source of cadmium (Sireli *et al*., 2006; Bala *et al*., 2012). High levels may be found in the liver and kidneys of adult animals, which puts consumers at high risk of cadmium toxicity (Okoye, 1994).

The global concern of meat contamination by heavy metals such as lead and cadmium is about the knowledge of the accumulation of these metals in the ecosystem and the hazard they produce through their ingestion by man (Adekunle *et al.*, 2003).

1.2 Statement of Research Problem

Zamfara State as a mining region has been associated significantly with deposition of heavy metals into the environment as reported by some authors (Alhassan *et al*., 2010; Medicines' Sans Frontiers' (MSF), 2012). The deposition of these metals led to an outbreak of lead poisoning in Zamfara State in 2010 (Blacksmith Institute, 2010), which resulted in the death of over 80 children within few months in two communities where mining of gold was taking place. A total of over 350-400 deaths were later reported in the communities. Concentrations reaching 700 μg/dL were detected in blood samples of children tested when compared to the blood lead level (BLL) definitions of Centre for Disease Control (CDC) of an elevated BLL in a child as BLL of ≥ 10 μg/dL for initiating public health actions. Lead concentrations above maximum tolerable limits of 0.5-10 mg/kg lead in normal plants and forage grasses have been reported from some Zamfara villages (Udiba *et al*., 2013). Transfer of lead to cattle through consumption of contaminated plants was also corroborated in literature (Swarup *et al*., 2005). Consumption of meat contaminated with lead constitutes risk to public health. There is no exposure limit below which lead is said to be safe (Patrick, 2009). Lead poisoning in humans can adversely affect

many organs and systems leading to numerous conditions such as high pressure, anaemia, kidney damage, mental retardation, shortened gestation period and other health related problems (Wagner, 1995), while young children are considered at great risk because of their ability to effectively absorb lead and thereby suffer mental and physical development retardation (Kocak *et al*., 2005). Animals and plant ecosystems are also affected by lead toxicity to varying degrees depending on species (Deni, 1993). The addition of lead to vegetation and animal surfaces can prevent the normal biochemical process that purifies the calcium pool in grazing animals and decomposer organisms (UNEP, 2013).

Cadmium is a non essential, toxic metal to which humans are exposed through a variety of pathways including food, particularly leafy vegetables, grains, cereals and meat (Goyer,1997), due to its accumulation in the food-chain (WHO, 2007). Its toxicity is attributed, in part, to its ability to accumulate in living things especially in body tissues (IPCS, 1992), and remain in the body for years. Most of the metal accumulate in the bones, liver and kidneys, where it can damage the functioning of those organs. People whose diets are deficient in zinc, copper, iron, calcium and vitamin D may be at higher risk for health complications from cadmium. These elements, which look and behave in a way that is chemically similar to cadmium, can be replaced by cadmium when the essential elements are in short supply. Bodily proteins that capture and metabolize essential minerals can also absorb cadmium particles due to its similar chemical behavior, (1ARC, 2009). Several studies indicate that cadmium accumulates in the soil, plants and water situated even far away from its primary source (Rogowska *et al*., 2007).

Grazing animals are directly affected by the consumption of forage and feed contaminated by lead and cadmium and somewhat indirectly by the up-take of these metals through plant roots. Some species of plants have the capacity to accumulate high concentrations of lead and cadmium (Deni, 1993; Udiba *et al*., 2013).

This study is therefore designed to determine the concentrations of lead in beef**,** mutton and camel meat sold in retail outlets in Gusau, Zamfara State and to assess the heavy metal risks associated with the measured levels of lead and cadmium in meat consumed in the study area.

1.3 Justification

Lead and cadmium have been found to have very high ingestion rates through food (Zhuang *et al*., 2009; Tsafe *et al*., 2012)**.** The purpose of this research was to convey the current status on lead and cadmium in meat of ruminants in the study area. In Nigeria there is lack of food intake diaries to monitor the intake of heavy metals. It is advocated that any legislation to check heavy metal exposure to humans should be based on genuine scientific evaluation of the available data (Gidlow, 2004). The health implications of heavy metals such as lead and cadmium have been fully documented (Tsafe *et al*., 2012). Significant contamination of seeds, plants and plant products with toxic chemical elements due to contaminated soil and water has been observed as a result of release of these toxicants into the sea, rivers and even into irrigation channels. Afterwards, the consumption of contaminated forage and vegetables constitutes an important route of animal and human exposure, respectively (Sajjad *et al*., 2009).

The lead pollution crisis in Zamfara State that occurred in 2010 in where over 10,000 people were estimated to have been affected (MSF, 2010; Lo *et al*., 2012; Geoffrey *et al*., 2013) was a crisis traced to environmental exposure to lead from the processing of lead-rich ore mined for gold extraction. Sicknesses and deaths among livestock were reported in the villages; therefore the consumption of such animal products (meat) might also be an important exposure route for humans (Shilo, 2010; Udiba *et al*., 2013; UNICEF, 2011). Studies in some Zamfara mining village soils during soil remediation exercises and after, implicated soil lead levels in many areas, including residential compounds, around drinking water sources and grinding mills exceeding the acceptable limit of soil-lead standard (400 parts per million (ppm) or 400 mg/kg) for areas of bare soil where children play (USEPA, 2011) and for residential areas (Lo *et al*., 2012). High concentrations of lead (up to more than 1,000 μg/l – 10 times higher than the exposure limit suggested by FAO for livestock) were often found in ponds, rivers and lakes sampled by the CDC mission (CDC, 2012; Dooyema *et al*. (2012).

Cadmium was listed in 2005 as the 7th of the 275 of the most hazardous substances in the environment following arsenic, lead, mercury, vinyl chloride, polychlorinated biphenyls and benzene by the Agency for Toxic Substances and Diseases (ATSDR), (2005). It has a long elimination half-life year and slowly accumulates in tissues overtime (Patrick, 2009). A number of studies in Nigeria have shown cadmium levels in liver and kidneys of goats, cattle, sheep, chicken above the permissible levels set by WHO, FAO (Iwuegbe, 2008; Akan, *et al*., 2010; Bala *et al*., 2012). Although no cadmium poisoning case has been reported in Zamfara State, Tsafe *et al*. (2012) reported cadmium levels of 3.08 mg/kg when compared to permissible levels of 0.2 mg/kg set by the FAO/WHO, (2011) vegetables grown in Zamfara. Udiba *et al***.** (2013) also

reported cadmium levels of 0.25mg/kg in drinking water points around mining villages slightly lower than 0.30mg/kg limits set by USEPA, (1992b).

Heavy metal contamination is serious all over the world especially in developing countries. Moreover, as heavy metal bio-accumulation increases in a nutrition deprived state, developing countries with higher prevalence of under nutrition are at a greater risk of heavy metal toxicity. Most countries have established parameters for monitoring safe level of intake of heavy metals in terms of health risk assessment using daily intake of metals (DIM), provisional tolerable weekly intake (PTWI), provisional tolerable monthly intake (PTMI), health risk Index (HRI) and total hazard quotient (THQ) for heavy metals as indicated in many studies of population at risk of heavy metal toxicity based on reference doses available for heavy metal intake by humans (Chandorkar and Deota, 2013). Meat from ruminants is widely consumed in Gusau, although the safety of these meats is in question, hence there was need to determine the concentrations of lead and cadmium and also assess the health risk for consumption of meat in Gusau, Zamfara State, Nigeria.

1.4 Aim and Objectives

1.4.1 Aim

The aim of this study was to determine lead and cadmium concentrations in beef, mutton and camel meat and to assess the risks associated with these metals through their consumption.

1.4.2 Objectives of study

The specific objectives are to:

i. determine lead and cadmium concentrations in beef, mutton and camel meat purchased from retail outlets in Gusau, Nigeria.

ii. assess the daily intake of metals (DIM), estimated daily intake of metals (EDIM), and hazard risk index (HRI) through consumption of lead and cadmium in beef, mutton and camel meat purchased from retail outlets in Gusau, Nigeria.

iii. determine the level of awareness of meat sellers and consumers on heavy metal poisoning in Gusau, Nigeria

1.5 Research Questions

i. Do beef, mutton and camel meat contain high amounts of lead and cadmium residues in Gusau, Nigeria?

ii. What is the risk for consuming beef, mutton and camel meat containing lead and cadmium?

iii. Are butchers, meat sellers and consumers aware of the probable health risk of lead and cadmium in beef, mutton and camel meat?

CHAPTER TWO

LITERATURE REVIEW

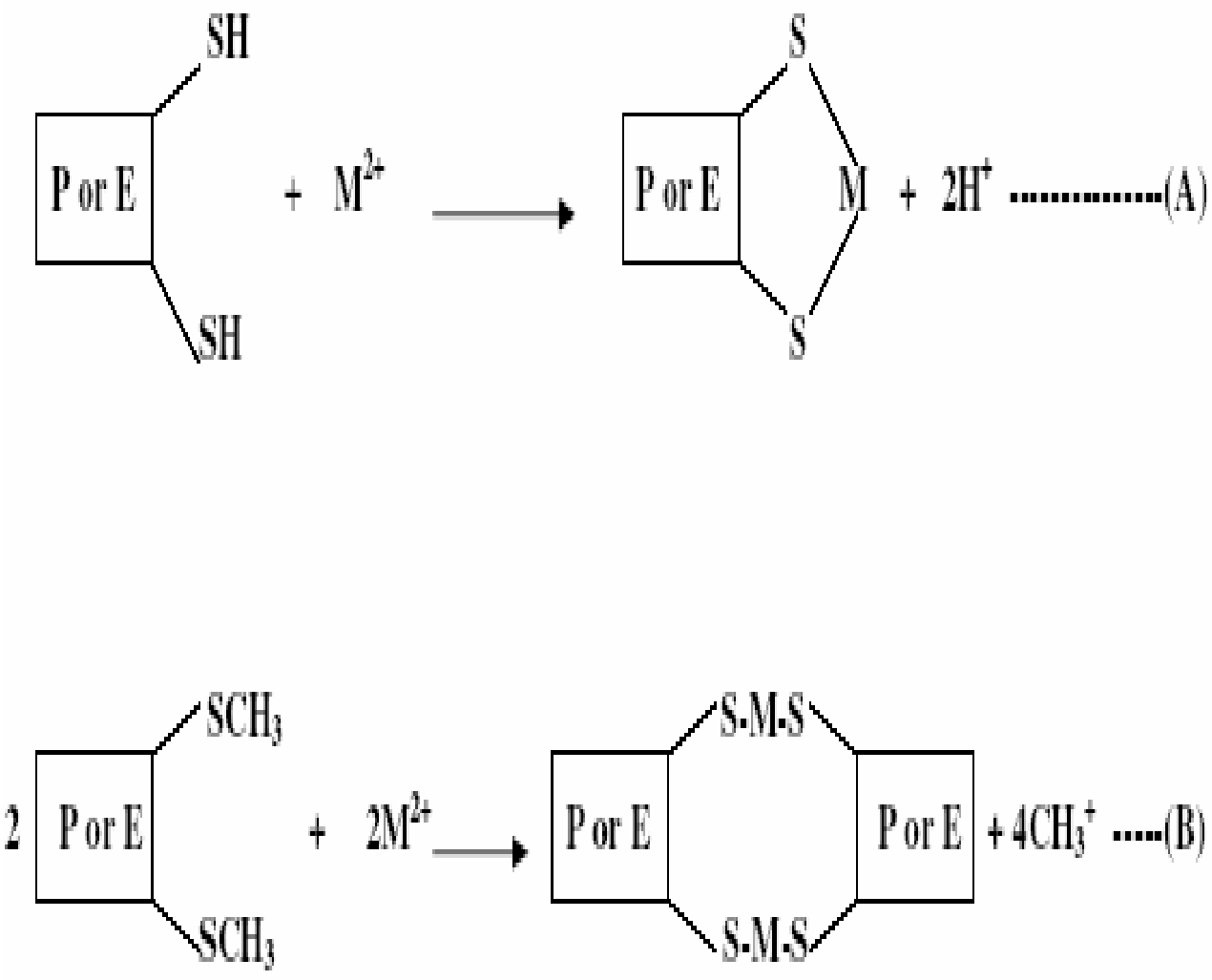
2.1 Heavy Metals

Heavy metals are an inexact term used to describe more than a dozen elements that are metals or metalloids which have densities above 5g/cm^3. They cannot be destroyed or degraded; they are found naturally in the earth, and become concentrated as a result of human activities. Common sources are from mining and industrial wastes; vehicle emissions; lead-acid batteries; fertilizers, paints and treated woods. There are 35 metals that are of concern because of occupational or residential exposure; 23 of these are the heavy metals: antimony, arsenic, bismuth, cadmium, cerium, chromium, cobalt, copper, gallium, gold, iron, lead, manganese, mercury, nickel, platinum, silver, tellurium, thallium, tin, uranium, vanadium and zinc (Sengupta, 2002). Heavy metals become toxic when they are not metabolized by the body and accumulate in the soft tissues. They may enter human body through food, water, air or by absorption through skin when in contact with humans during agricultural and in industrial (manufacturing, pharmaceutical), and/ or residential settings. Ingestion is the most common route of exposure in children (Robert, 1999).

Many metals are useful to life, for example iron, as oxygen carrier in hemoglobin; calcium and phosphorus in bone building and magnesium in chlorophyll formation, however with their increased concentration in the environment, they produce toxicity, retard growth and in ultimate destruction (death) of living organisms (Aremu *et al*., 2010). They are also associated with adverse health effects, including allergic reactions (beryllium, chromium), neurotoxicity (lead), nephrotoxicity (mercuric chloride, cadmium chloride) and cancer (arsenic)(Krishna and

Ramachandra 2009). In general, heavy metals comprise a group of elements that have no known function in the body and in fact are believed to be harmful to the body (Lars, 2003).

The poisoning effects of heavy metals on both humans and animals are due to their interference with the normal body biochemistry in the normal metabolic processes. When ingested, in the acid medium of the stomach, they are converted to their stable oxidation states (Zn^{2+}, Pb^{2+}, Cd^{2+}, As^{2+}, As^{3+}, Hg^{2+} and Ag^{+}) and combine with the body's biomolecules such as proteins and enzymes to form strong and stable chemical bonds. The equations in Figure 1.1 show reactions of heavy metal during bond formation with the sulphydryl groups (-SH) of cysteine and sulphur atoms of methionine (-SCH3) (Ogwuegbu and Ijioma, 2003).



Where: (A) = Intermolecular bonding; (B) = Intermolecular bonding; P = Protein; E = Enzyme; M = Metal.

Figure 1.1 Reactions of Heavy Metals with Functional Groups of Proteins/Enzymes.

The hydrogen atoms or the metal groups in the above case are replaced by the poisoning metal and the enzyme is thus inhibited from functioning, whereas the protein–metal compound acts as a substrate and reacts with a metabolic enzyme. Enzymes (E) react with substrates (S) in either the lock-and-key pattern or the induced-fit pattern. In both cases, a substrate fits into an enzyme in a highly specific fashion, due to enzyme chirality, to form an enzyme–substrate complex (E-S*) as follows (Holum, 1983).

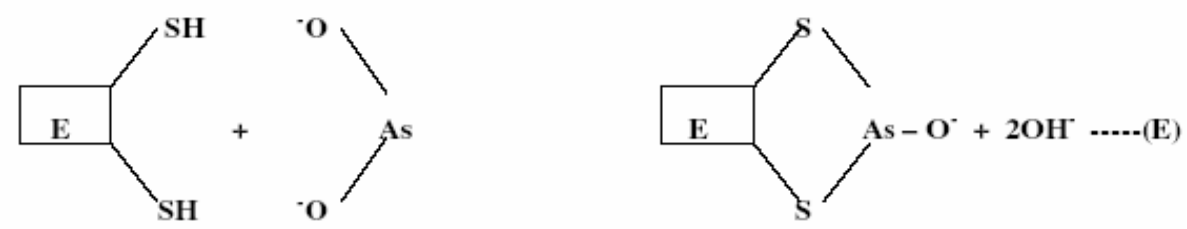
$$E + S \; E\text{-}S \; E - S^* \; E - P \; E + P$$

Where (E = Enzyme; S = Substrate; P = Product; * = Activated Complex) While at the E-S, E–S* and E-P states, an enzyme cannot accommodate any other substrate until it is freed. Sometimes, the enzymes for an entire sequence coexist together in one multi-enzyme complex consisting of three or four enzymes. The product from one enzyme reacts with a second enzyme in a chain process, with the last enzyme yielding the final product as follows:

$A \xrightarrow{E1} B \xrightarrow{E2} C \xrightarrow{E3} D \xrightarrow{E4} \mathbf{F}$ (E_1---- E_4 are enzymes).

The final product (F) goes back to react with the first enzyme thereby inhibiting further reaction since it is not the starting material for the process. Hence, the enzyme E1 becomes incapable of accommodating any other substrate until F leaves and F can only leave if the body utilizes it. If the body cannot utilize the product formed from the heavy metal – protein substrate, there will be a permanent blockage of the enzyme E1, which then cannot initiate any other bio-reaction of its function. Therefore, the metal remains embedded in the tissue, and will result in toxicities of various degrees (Holum, 1983). Furthermore, a metal ion in the body's metallo-enzyme can be conveniently replaced by another metal ion of similar size. Thus Cd^{2+} can replace Zn^{2+} in some dehydrogenating enzymes, leading to cadmium toxicity. In the process of inhibition, the structure

of a protein molecule can be mutilated to a bio-inactive form, and in the case of an enzyme can be completely destroyed. For example, toxic As3+ occurs in herbicide, fungicides and insecticides, and can attack –SH groups in enzymes to inhibit their bioactivities as shown below (Ogwuegbu and Ijioma, 2003).



In their most stable oxidation states, heavy metals form very stable biotoxic compounds with the body's bio-molecules, which become difficult to be dissociated, due to their bio-stabilities, during extraction from the body by medical detoxification therapy (Duruibe *et al*., 2007).

2.2 Lead

Lead is a chemical element in the carbon group with symbol Pb (from Latin: *plumbum*) and atomic number 82. It is a soft and malleable metal, which is regarded as a heavy metal and poor metal. Metallic lead has a bluish-white color after being freshly cut, but it soon tarnishes to a dull grayish color when exposed to air. It has a shiny chrome-silver luster when it is melted into a liquid and is a bright and silvery metal with a very slight shade of blue in a dry atmosphere (Thurmer, *et al*., 2002). Upon contact with air, it begins to tarnish by forming a complex mixture of compounds depending on the conditions. The colour of the compounds can vary. The tarnish layer can contain significant amounts of carbonates and hydroxyl carbonates (Tétreault *et al*., 1998). It has a few characteristic properties: high density, softness, ductility and malleability,

poor electrical conductivity compared to other metals, high resistance to corrosion, and ability to react with organic chemicals.

2.2.1 Brief history of lead

Lead has been commonly used for thousands of years because it is widespread, easy to extract and easy to work with. It is highly malleable as well as easy to smelt. Metallic lead beads dating back to 6400 BC have been found in Çatalhöyük in modern-day Turkey Callataÿ (Heskel, 1983). In the early Bronze Age, lead was used with antimony and arsenic (Callataÿ, 2005).

2.2.2 Sources of lead

Lead occurs naturally in the environment and is also an environmental pollutant (Regan and Turner, 2009). Causes of environmental pollution include human activities e.g. industrial use of lead, such as found in facilities that process lead-acid batteries or produce lead wire or pipes, and metal recycling and foundries (Rossi, 2008). The WHO estimated that the sources of lead exposure for children are dust (45%), food (47%), water (6%) and air (1%) respectively.

2.2.2.1 Natural sources

Lead occurs in all rocks, soils and dust, usually ranging from 2 to 200 ppm. The total amount of lead in the earth's crust is 3.1×10^{14} metric tonnes. Some soils have relatively high concentrations of lead, where the underlying parent rock has significant lead content. Lead contents of water are generally low, but significant amount of lead-rich dust and vapours are carried in the air, from windblown materials and volcanoes (Tétrault *et al.*, 1998).

2.2.2.2 Anthropogenic sources of lead

Production of lead: Mining, smelting and refining of lead and other metals have in recent times caused large emissions of lead.

Environmental pollution by lead: Mobile sources (i.e vehicles running on leaded petrol) continue to be a major contributor of atmospheric lead which in turn gives rise to elevated lead level in soils, dust and surface water (Grant, 2009).

Lead Containing Products: Lead can be found in products such as cosmetic from the Middle East, South Asia, and parts of Africa; and from some toys (Guidotti and Ragain, 2007). In 2007, millions of toys made in China were recalled from multiple countries owing to safety hazards including lead paint (CNN, 2009). Vinyl mini-blinds, found especially in older housing, may contain lead (Ragan and Turner, 2009). Lead is commonly incorporated into herbal remedies such as Indian Ayurvedic preparations and remedies of Chinese origin (Patrick, 2006). Ceramic glaze, solder cans, medical instruments, consuming animals hunted with bullets often contains lead (Hunt *et al*., 2009).

According to Siddiqui and Gayatri (2008) the permisibe levels of lead in ambient air is 0.75 mg/m^3 for sensitive area, 1.0 mg/m^3 for residential areas, 1.5 mg/m^3 for industrial areas in the water 0.05mg/L, for drinking water while for effluents: 0.10 mg/L for discharge of industrial effluents in inland surface water, which are generally in line with internationally set standards.

2.2.3 Harmful effects of lead

The great disadvantage of lead has always been that it is poisonous to animals, including humans; it is a neurotoxin that accumulates both in soft tissues and the bones. It damages the

nervous system and causes brain disorders. Excessive lead also causes blood disorders in mammals; Lead poisoning has been documented from ancient Rome, ancient Greece, and ancient China (Hodge, 1992). Although lead poisoning is one of the oldest known work and environmental hazards, the modern understanding of the small amount of lead necessary to cause harm did not come about until the latter half of the 20th century. No safe threshold for lead exposure has been discovered that is, there is no known amount of lead that is too small to cause the body harm (Needleman, 2004). The acute oral lethal dose in various animal species has been calculated to be 50 to 400 mg/kg in calves, 600 to 800 mg/kg in cattle, 160 to 600 mg/kg in birds, and 30 to 40 g in sheep and 400mg/kg in humans (ATSDR, 2005).

Lead contamination in the environment and its effects are seen as lead contaminates the ecosystem and is deposited in vegetation, ground and water surfaces. It affects all components of the environment, if accumulated in certain chemical environments it will be transformed in such a way as to increase its solubility (e.g., the formations of lead sulphate in soils), its bioavailability or its toxicity (USEPA, 1986). Populations of plants, micro-organisms and invertebrates may be adversely affected by lead concentrations of 500 to 1,000 ppm, allowing more lead-tolerant populations of the same or different species to take their place. This will change the type of ecosystem present. The addition of lead to vegetation and animal surfaces can prevent the normal biochemical process that purifies the calcium pool in grazing animals and decomposer organisms (UNEP 2013).

2.2.4 Lead poisoning

Lead poisoning (also known as *plumbism*, *colica*, *pictonum*, *saturnism*, *Devon colic*, or *painter's colic*) is a medical condition in humans and other vertebrates caused by increased levels of lead in the body. Classically, "lead poisoning" or "lead intoxication" has been defined as exposure to high levels of lead typically associated with severe health effects (Grant, 2009). Poisoning is a pattern of symptoms that occur with toxic effects from mid to high levels of exposure; toxicity is a wider spectrum of effects, including subclinical symptoms (Guidotti and Ragain, 2007).

The amount of lead in the blood and tissues, as well as the time course of exposure, determines toxicity (Pearson and Schonfeild, 2003). Lead poisoning may be acute (from intense exposure of short duration) or chronic (from repeated low-level exposures over a prolonged period), but the latter is much more common (Trevor *et al*., 2007). When blood lead levels are recorded, the results indicate how much lead is circulating within the blood stream, not the amount being stored in the body. Diagnosis and treatment of lead exposure are based on blood lead level (BLL) concentrations measured in either micrograms per deciliter (µg/dl), or micrograms per 100 grams (µg/100 g) of the whole blood, which are numerically equivalent. The US Centers for Disease Control and Prevention and the World Health Organization state that a blood lead level of 10 µg/dL or above is a cause for concern; however, lead may impair development and have harmful health effects even at lower levels, and there is no known safe exposure level (Barbosa *et al*., 2005: Rossi, 2008). The CDC has set the standard elevated blood lead level for adults to be 10 µg/dl of the whole blood. For children however, the concentration is set much lower at 5 µg/dl of blood as from the year 2012 from a previous 10 µg/dl as children are especially prone to the health effects of lead (Guidotti and Ragain, 2007). Authorities such as the American

Academy of Pediatrics define lead poisoning as blood lead levels higher than 10 μg/dL (Ragan and Turner, 2009).

2.2.4.1 Lead poisoning in humans

Lead interferes with a variety of body processes and is toxic to many organs and tissues including the heart, bones, intestines, kidneys, and reproductive and nervous systems. It interferes with the development of the nervous system and is therefore particularly toxic to children, causing potentially permanent learning and behavioral disorders. Symptoms include abdominal pain, confusion, headache, anaemia, irritability, and in severe cases seizures, coma, and death.

Toxicity of lead is closely related to age, sex, route of exposure, level of intake, solubility, metal oxidation stage, retention percentage and duration of exposure, frequency of intake, absorption rate and mechanisms, efficiency of excretion (Pearson and Schonfeld, 2003). The main target for lead toxicity is the nervous system, both in adults and children. Long-term exposure of adults to lead can result in decreased performance in some tests that measure functions of the nervous system (Tollestrup *et al*., 1995). Long-term exposure to lead or its salts (especially soluble salts or the strong oxidant, PbO_2) can cause nephropathy, and colic-like abdominal pains. It may also cause weakness of the fingers, wrists, or ankles. Lead exposure also causes small increases in blood pressure, particularly in middle-aged and older people and can cause aneamia. Exposure to high lead levels can severely damage the brain and kidneys in adults or children and ultimately cause death. In pregnant women, high levels of exposure to lead may cause miscarriage. Chronic, high-level exposures have been shown to reduce fertility in males (Golub, 2005).

Lead also damages nervous connections (especially in young children) and cause blood and brain disorders. Lead poisoning typically results from ingestion of food or water contaminated with lead; but may also occur after accidental ingestion of contaminated soil, dust, or lead-based paint. It is rapidly absorbed into the bloodstream and is believed to have adverse effects on the central nervous system, the cardiovascular system, kidneys, and the immune system (Bergeson, 2008). The component limit of lead (1.0 μg/g) is a test benchmark for pharmaceuticals, representing the maximum daily intake of an individual. However, even at this low level, a prolonged intake can be hazardous to human beings (Jagadish, 2010).

The concern about the role of lead in cognitive deficits in children has brought about widespread reduction in its use. Lead exposure has been linked to learning disabilities (Hu, 1991). Most cases of adult elevated blood lead levels are workplace-related (NIOSH, 2007). High blood levels are associated with delayed puberty in girls (Schoeters *et al.*, 2008). Lead has been shown many times to permanently reduce the cognitive capacity of children at extremely low levels of exposure (Needleman *et al.*, 1990).

Lead salts used in pottery glazes have on occasions caused poisoning, when acidic drinks, such as fruit juices, have leached lead ions out of the glaze. It has been suggested that what was known as "Devon colic" arose from the use of lead-lined presses to extract apple juice in the manufacture of cider. Lead is considered to be particularly harmful to women's ability to reproduce. Lead (II) acetate (also known as *sugar of lead*) was used in the Roman Empire as a sweetener for wine, and some consider this a plausible explanation for the dementia of many

Roman emperors, and, that chronic lead poisoning contributed to the empire's gradual decline (Angier, 2007).

2.2.4.1 Lead poisoning in animals

The traditional system of raising livestock in Nigeria where animals are kept on a free range could be a good indicator of the presence of lead in the environment. Cattle and other ruminants that graze on such environment and drink water from ponds, streams, rivers and other contaminated sources may bio accumulate these metals in their organs and other tissues. When such animals are slaughtered and consumed by humans, the metal accumulates in human tissues and organs (Miranda *et al*., 2005).

Lead poisoning occurs in farm animals' especially young cattle, sheep and horses. In cattle, lead poisoning is usually due to accidental ingestion over a short period of time due to natural curiosity, propensity to lick and lack of oral discrimination. It has been estimated that 150,000 cattle worldwide are exposed annually to toxic levels of lead and at least 20,000 acute deaths occur (Braton and Zmudzki, 1984). The concentration of lead residues in tissues of farm animals depends on the route of entry and exposure to the environmental pollutants (air, water and plants) for long period. Most orally ingested lead is deposited in the skeleton (Hu *et al*., 1991). Initially, lead is deposited in the bone until a possible threshold is reached where it is deposited in other tissues like the kidneys. About 82% of lead is excreted in feaces and urine, 0.5% in urine and the rest 17.5% remains in tissues and body organs (Baars *et al*., 1988). The degree of absorption of lead is influenced by dietary factors such as calcium or iron levels (Siddiqui and Gayatri, 2008).

In ruminants, metallic lead poisoning results from gradual conversion of lead particles to lead acetate due to acidity of the stomach. This provides a reservoir from which lead can continue to be absorbed into the bodies of cattle, sheep and goats (Drage, 2009). In a study, it was observed that that tissue accumulation in animals was related to concentration of to lead in the environment (Miranda *et al*., 2005). Animals are affected by lead toxicity to varying degrees depending on species (Deni, 1993). Lead blood concentrations of above 4 µg/dl can produce observable clinical symptoms in domestic animals. The USEPA report generalizes that a regular diet of 2-8 mg of lead per kilogram of body weight per day, over an extended period of time, will cause death in most animals (Deni, 1993). Clinical signs could be acute, sub-acute and chronic because of the differences in the dose of lead consumed and the resulting severity of symptoms. Much of what is known about human lead toxicity and its effects is derived from animal studies (Belinger, 2004). Animals are used to test the effects of treatments, such as chelating agents (Pedig and Arent, 2008) and to provide information on the patho-physiology of lead poisoning and its disposition in the body (Neathery and Miller, 1975).

Pet animals are also susceptible to the effects of lead toxicity. Sources of lead exposure in pets can be the same as those that present health threats to humans sharing the same environment, such as paint and blinds, and the presence of lead in some toys. Lead poisoning in a pet dog may indicate that children in the same household are at increased risk of poisoning. In wildlife, Turkey, vultures (*Cathartes aura*) and California condors (*Gymnogyps califonianus*) can be poisoned when they eat carcasses of animals shot with lead pellets. Lead is one of the leading causes of toxicity in waterfowls and has been known to cause die-offs of wild bird populations (Ligthfoot and Yeager, 2008).

2.2.5 Mechanisms of lead poisoning

In the human body, lead inhibits porphobilinogen synthase and ferrochelatase, preventing both porphobilinogen formation and the incorporation of iron into protoporphyrin IX, the final step in haeme synthesis. This causes ineffective haeme synthesis and subsequent microcytic anaemia (Cohen, 1981). At lower levels, it acts as a calcium analogue, interfering with ion channels during nerve conduction. This is one of the mechanisms by which it interferes with cognition.

2.2.6 Clinical signs of lead poisoning.

Lead poisoning can cause a variety of symptoms and signs which vary depending on the individual and the duration of lead exposure. Symptoms are nonspecific and may be subtle; an individual with elevated lead levels may be presented with no symptoms. Symptoms usually develop over weeks to months as lead builds up in the body during a chronic exposure, but acute symptoms from brief, intense exposures also occur (Karry *et al*., 2008). Symptoms from exposure to organic lead, which is probably more toxic than inorganic lead due to its lipid solubility, occur rapidly (Timbrell, 2008). Poisoning by organic lead compounds has symptoms predominantly in the central nervous system, such as insomnia, delirium, cognitive deficits, tremor, hallucinations, and convulsions (Ragan and Turner, 2009).

Symptoms may be different in adults and children; the main symptoms in adults are headache, abdominal pain, memory loss, kidney failure, male reproductive problems, and weakness, pain, or tingling in the extremities (Pearce, 2007). Early symptoms of lead poisoning in adults are commonly nonspecific and include depression, loss of appetite, intermittent abdominal pain, nausea, diarrheoa, constipation, and muscle pain (Patrick, 2006). Other early signs in adults

include malaise, fatigue, decreased libido, and problems with sleep. Unusual tastes in the mouth and personality changes are also early signs (Karry *et al*., 2008). In adults, symptoms can occur at levels above 40 μg/dL, but are more likely to occur only above 50–60 μg/dl, abdominal colic, involving paroxysms of pain, may appear at blood lead levels greater than 80 μg/dL (Karry *et al*., 2008). Signs that occur in adults at blood lead levels exceeding 100 μg/dL include wrist drop and foot drop, and signs of encephalopathy (a condition characterized by brain swelling), such as those that accompany increased pressure within the skull, delirium, coma, seizures, and headache (Bellinger, 2004).

Symptoms begin to appear in children generally at around 60 μg/dL (Needleman, 2004). However, the lead levels at which symptoms appear vary widely depending on unknown characteristics of each individual (Bellinger, 2004). At blood lead levels between 25 and 60 μg/dL, neuropsychiatric effects such as delayed reaction times, irritability, and difficulty concentrating, as well as slowed motor nerve conduction and headache can occur. Anemia may appear at blood lead levels higher than 50 μg/dL (Patrick, 2006). In children, signs of encephalopathy such as bizarre behaviour, dis-coordination, and apathy occur at lead levels exceeding 70 μg/dL (Landrigan *et al*., 2002). For both adults and children, it is rare to be asymptomatic if blood lead levels exceed 100 μg/dL (Karry *et al*., 2008).

2.2.7 Diagnosis of lead poisoning

Diagnosis includes determining the clinical signs and the medical history, with inquiry into possible routes of exposure (Vedentam, 2007). Clinical toxicologists, medical specialists in the area of poisoning, may be involved in diagnosis and treatment. The main tool in diagnosing and

assessing the severity of lead poisoning is laboratory analysis of the blood lead level (BLL) (Karry *et al.*, 2008).

Blood film examination may reveal basophilic stippling of red blood cells as well as the changes normally associated with microcytosis and hypochromasia (Ekong *et al.*,2006). However, basophilic stippling is also seen in unrelated conditions, such as megaloblastic aneamia caused by vitamin B12 (cynocolbalamin) and folate deficiencies (Shadick et *al*., 2000).

Exposure to lead also can be evaluated by measuring erythrocyte protoporphyrin (EP) in blood samples (Patrick, 2006). EP is known to increase when the amount of lead in the blood is high, with a delay of a few weeks. Thus EP levels in conjunction with blood lead levels can suggest the time period of exposure; if blood lead levels are high with normal EP levels; this suggests a recent exposure (Karry *et al*., 2008).

Blood lead levels are indicators, mainly of recent or current lead exposure, not of total body burden (Vaziri, 2008). Lead in bones can be measured noninvasively by X-ray fluorescence; this may be the best measure of cumulative exposure and total body burden (Kosnett *et al.*, 2007). However this method is not widely available and is mainly used for research rather than routine diagnosis (Brodkin *et al*., 2007). Another radiographic sign of elevated lead levels is the presence of radiodense lines called lead lines at the metaphysis in the long bones of growing children, especially around the knees. These lead lines, caused by increased calcification due to disrupted metabolism in the growing bones, become wider as the duration of lead exposure increases (Gwiazda *et al*., 2005). X-rays may also reveal lead-containing foreign materials such as paint chips in the gastrointestinal tract (Kosnett *et al*., 2007).

Faecal lead content that is measured over the course of a few days may also be an accurate way to estimate the overall amount of childhood lead intake. This form of measurement may serve as a useful way to see the extent of oral lead exposure from all the diet and environmental sources of lead, (Gwiazda *et al*., 2005)

Lead poisoning present symptoms that are similar to other conditions and may be easily misdiagnosed. Conditions that present similar symtoms and are part of lead poisoning differentials include carpal tunnel syndrome, Guillain-Barré syndrome, renal colic, appendicitis, encephalitis in adults, and viral gastroenteritis in children. Other differential diagnoses in children include constipation, abdominal colic, iron deficiency, subdural haematoma, neoplasms of the central nervous system, emotional and behaviour disorders, and mental retardation (Mycyk, 2005).

2.2.8 Treatment for lead poisoning

The mainstay treatment for lead poisoning are removal from the source of lead and, for individuals with significantly high blood lead levels or who have symptoms of poisoning, chelation therapy is usually instituted. Treatment of iron, calcium, and zinc deficiencies, which are associated with increased lead absorption, is another part of treatment for lead poisoning (Kosnett *et al*., 2007). When lead-containing materials are present in the gastrointestinal tract (as evidenced by abdominal X-rays), whole bowel irrigation, cathartics, endoscopy, or even surgical removal may be used to eliminate the materials from the gut and prevent further exposure (Olston, 2007). Animals or humans shot with lead containing bullets and shrapnel may also be exposed to lead poisoning and may require surgical removal of the bullet especially if located in or near fluid-filled or synovial spaces (Dart *et al*., 2004). In case of encephalopathy,

anticonvulsants may be given to control seizures, and treatments to control swelling of the brain involve the use of corticosteroids (anti-inflammatory) and mannitol (diuretics). Treatment of organic lead poisoning involves removing the lead compound from the skin, preventing further exposure, treating seizures, and possibly chelation therapy for people with high blood lead concentrations (Kosnett *et al*., 2007).

Chelation therapy**:** It is a system used to decrease blood lead concentrations acutely. A chelating agent is a molecule with at least two negatively charged groups that allows it to form complexes with metal ions with multiple positive charges, such as lead. The chelate that is thus formed is nontoxic (Menkes, 2006) and can be excreted in the urine, initially at up to 50 times the normal rate (Lightfoot and Yeager 2008). The chelating agents used for treatment of lead poisoning are edetate disodium calcium ($CaNa_2EDTA$), dimercaprol (BAL), which are injected, succimer (dimercaptorsuccinic acid) and d-penicillamine, which are administered orally when blood lead levels are greater than 70µg/dL. Chelation therapy is used in cases of acute lead poisoning, severe poisoning, and encephalopathy (Olson, 2007), and is considered for people with blood lead levels above 25 µg/dL. Chelation therapy is of limited value for cases of chronic exposure to low levels of lead (Meyer *et al*., 2008). Chelation therapy is usually stopped when symptoms resolve or when blood lead levels return to premorbid levels (Kosnett *et al*., 2007).

2.2.9 Prevention of lead poisoning

Several international conventions have acknowledged the importance of exposure to lead as a key public health issue. These conventions include are the following;

i. The 1989 convention on the Rights of the Child

ii. Agenda 21 adopted by the United Nations Conference on Environment and Development in 1992

iii. The 1997 Declaration on the Environment by the leaders of the G8 nations (on Children's Environmental Health.

iv. The OECD Declaration on Lead Risk Reduction.

According to Centers for Disease Control and Prevention (CDC, 2002) public health measures should continue to be directed at the reduction and prevention of exposure to lead by reducing the use of the metal and its compounds and by minimizing lead containing emissions that result in human exposures. This can be achieved by

i. Banning the use of lead additives in fuels and removing lead from petrol as soon as possible

ii. Safe mining practices

iv. Phasing out of lead bases paints, painting over intact old paint on walls or salvaged doors and windows (do not disturb the surface) when redecorating or renovating the home to reduce the amount of lead dust. Pregnant or breastfeeding women and children under five should not be present in the home.

iv. Cleaning the house regularly and ensuring there is no build-up of dust, wetting dusty floors, ledges, windowsills and other flat surfaces to minimize the risk of lead containing dust getting into the air.

v. Identifying, reducing and eliminating lead used in traditional medicines and cosmetics

vi. Improving identification of population at risk of exposure on the basis of monitoring systems.

vii Improving procedures of health risk assessment.

viii. Promotion of understanding and awareness of exposure to lead.

ix. Developing local, national and international monitoring and analytical quality control programmes and increasing emphasis on adequate nutrition, health care and attention to socio-economic conditions that may exacerbate the effects of lead.

2.3 Incidences of Lead Toxicities in Nigeria

In Nigeria today different types of illnesses have been reported to be associated with heavy metals. The major heavy metal poisoning cases in Nigeria were believed to be associated with lead poisoning. The most recent reported incidences of lead poisoning in Nigeria include the Zamfara lead poisoning which claimed the lives of over 500 children within seven months in 2010. Between January and July, illegal miners from seven villages in Zamfara State, brought rocks containing gold ore into the villages from small-scale mining operations. The gold containing rocks (ores) also contained extremely high levels of lead. The ore was crushed inside village compounds, spreading lead dust throughout the community. Joint field studies were carried out by International Organizations like Médecins Sans Frontières (MSF), US Centers for Disease Control and Prevention (CDC), Blacksmith Institute (BI), World Health Organisation (WHO) in collaboration with affected Local Government Authorities, Zamfara State Government state and the Federal Government of Nigeria to measure the blood-lead concentrations in 113 young children in the villages of Yargalma and Dareta of Zamfara State, Nigeria

In the study, all of the children (100%) of the children had blood-lead levels (BLL) exceeding 10 μg/ dL (the international standard for the maximum safe levels of lead in blood), 96% of the tested children had BLL exceeding 45 μg/dL, and 84% had more than 70 μg/dL in their blood (Blacksmith Institute, 2010; MSF, 2010). In addition 78 deaths were recorded in Yargalma village where 30% of the population was less than 5 years old and 40 deaths in Dareta in which 20% of the population was less than 5 years old), totaling 118 deaths in these two communities since the beginning of 2010. Ninety five percent of all deaths were recorded among children under the age of five. As of September 2010, it was estimated that a total of 2,500 children in those villages have life-threatening levels of lead in their blood. Further investigations identified at least five additional villages where similar ore processing activities are common. In many areas in all villages sampled, including family homes and compounds, the soil lead concentration exceeded 100,000 ppm, far above the recommended maximum of 400 ppm considered acceptable for residential areas by the USEPA. Ingestion of contaminated soil and air inhalation has been the primary pathway of lead exposure. The affected children were generally reported to show severe health symptoms.

Galadima *et al*. (2011) conducted a study on the levels of heavy metals in effluent water from student halls of Usmanu Danfodiyo University, Sokoto, Nigeria. The results showed the presence of lead at concentrations that are more than 20 times the recommended international limits. The pollution was attributed to continuous use of contaminated water by the students and the disposal of carrier wastes by the sellers of different items in the residential premises of the students. The river provides fresh irrigation water to local farmers, indicating that human absorption through food chain and occupational exposure is very possible. Ladigbolu and Balogun (2011) reported

lead concentrations of 405.0 μg/g in soil profile sediments from Ibadan, Oyo State, in which the pollution was attributed to population growth, urbanization, agricultural activities and uncontrolled direct dumping of wastes and sewages into aquatic environment. On a similar trend Nubi *et al* (2011) showed marine water from Lagos coastal areas to contain lead concentrations, far greater than the acceptable WHO and FEPA limits.

2.4 Cadmium

Cadmium is a chemical element with the symbol Cd and atomic number 48. This soft, bluish-white metal is chemically similar to the two other stable metals in group 12 of the periodic table, zinc and mercury. Like zinc, the average concentration of cadmium in the Earth's crust is between 0.1 and 0.5 parts per million (ppm). It occurs as a minor component in most zinc ores and therefore is a byproduct of zinc production. Unlike other metals, cadmium is resistant to corrosion and as a result it is used as a protective layer when deposited on other metals. As a bulk metal, cadmium is insoluble in water and is not flammable; however, in its powdered form it may burn and release toxic fumes (CSEM, 2011) like brown amorphous cadmium oxide (Cd O); the crystalline form of this compound is dark red which changes colour when heated, similar to zinc oxide. Hydrochloric acid, sulphuric acid and nitric acid react with cadmium to form cadmium chloride ($CdCl_2$), cadmium sulphate ($CdSO_4$), or cadmium nitrate ($Cd(NO_3)_2$ respectively (Holleman *et al*., 1985). The structures of many cadmium complexes with nucleobases, amino acids and vitamins have been determined (Carballo *et al*., 2013).

Naturally occurring cadmium is composed of eight isotopes. Two of them are naturally radioactive, and three are expected to decay but have not been experimentally confirmed to do so. The two natural radioactive isotopes are ^{113}Cd (beta decay, half-life is 7.7×10^{15} years) and

^{116}Cd (two-neutrino double beta decay, half-life is 2.9×10^{19} years). The other three are ^{106}Cd, ^{108}Cd (both double electron capture), and ^{114}Cd (double beta decay); only lower limits on their half-life times have been set. At least three isotopes – ^{110}Cd, ^{111}Cd, and ^{112}Cd – are stable (Audi *et al*., 2003).

2.4.1 Brief history of cadmium

Cadmium (Latin *cadmia*, Greek *καδμεία* meaning "calamine", a cadmium-bearing mixture of minerals, which was named after the Greek mythological character Κάδμος, Cadmus, the founder of Thebes) was discovered simultaneously in 1817 by Friedrich Stromeyer and Karl Samuel Leberecht Hermann, both in Germany, as an impurity in zinc carbonate (Morrow , 2010). Stromeyer found the new element as an impurity in zinc carbonate (calamine), and, for 100 years, Germany is the only country that remained the only important producer of the metal. Even though cadmium and its compounds may be toxic in certain forms and concentrations, the British Pharmaceutical Codex from 1907 states that cadmium iodide was used as a medication to treat enlarged joints, scrofulous glands, and chilblains (painful inflammation of the skin, feet and ears due to cold) (Dunglison, 1866).

2.4.2 Sources of cadmium

2.4.2.1 Environmental and industrial sources

Cadmium makes up about 0.1 ppm of the Earth's crust. Compared with the more abundant 65 ppm zinc, cadmium is rare (Wedepohl, 1995). No significant deposits of cadmium-containing ores are known. Cadmim sulphate, the only cadmium mineral of importance, is nearly always associated with zinc sulphate. This association is caused by the geochemical similarity between

zinc and cadmium which makes geological separation unlikely. As a consequence, cadmium is produced mainly as a byproduct from mining, smelting, and refining sulphide ores of zinc, and, to a lesser degree, lead and copper. Small amounts of cadmium, about 10%, are produced from secondary sources, mainly from dust generated by recycling iron and steel scrap (Ayres *et al*., 2003).

Rocks mined to produce phosphate fertilizers contain varying amounts of cadmium, leading to a cadmium concentration of up to 300 mg/kg in the produced phosphate fertilizers therefore giving rise to high cadmium concentrations in agricultural treated soils (Jiao *et al*., 2004). Coal can contain significant amounts of cadmium, which ends up mostly in the flue dust. Cadmium is a common impurity in zinc ores, and it is most often isolated during the production of zinc. Some zinc ores concentrates from sulphidic zinc ores contain up to 1.4% of cadmium.

2.4.2.2 Food and drinking water

Cadmium contained in soil and water can be taken up by certain crops and aquatic organisms and accumulate in the food-chain (IPCS, 1992). Food constitutes the main environmental source of cadmium for non-smokers. Highest cadmium levels are found in the kidney and liver of mammals fed with cadmium-rich diets and in certain species of oysters, scallops, mussels and crustaceans. Lower cadmium concentrations are found in vegetables, cereals and starchy roots. Owing to the larger consumption of such food items, they represent the greater part of daily cadmium intake in most populations (WHO, 2007). Some crops, such as rice, can accumulate high concentrations of cadmium if grown on cadmium-polluted soil. Acidification of cadmium-containing soils may increase the cadmium concentrations in crops.

Cadmium exposure from drinking-water is relatively unimportant compared with exposure from the diet. However, impurities in the zinc of galvanized pipes and solders in fittings, water heaters, water coolers and taps can sometimes lead to increased cadmium levels in drinking-water (WHO, 2008).

2.4.3 Uses and applications of cadmium

Cadmium has many common industrial uses as it is a key component in battery production, is present in cadmium pigments coatings (electroplating) used in the aircraft industry due to the ability to resist corrosion when applied to steel components (Buxbaun and Pfaff, 2005). It is used as a barrier to control neutrons in nuclear fission.

Cadmium oxide is used in black and white television phosphors and in the blue and green phosphors for color television picture tubes (Lee and His, 2002). Cadmium sulphide (CdS) is used as a photoconductive surface coating for photocopier drums. In paint pigments, CdS is used as a yellow pigment. Cadmium selenide can be used as red pigment, commonly called cadmium red, acrylics, and other paint and pigment formulations (Buxbaun and Pfaff, 2005).

Helium–cadmium lasers are a common source of blue-ultraviolet laser light used in fluorescence microscopes and various laboratory experiments (Nambiar, 2006). Cadmium is a component of some compound semiconductors, such as cadmium sulphide, cadmium selenide, and cadmium telluride, which can be used for light detection or solar cells therefore may be utilized as an infrared detector or switch for example in remote control devices (Scoulous *et al.*, 2001).

In molecular biology, cadmium is used to block voltage-dependent calcium channels from fluxing calcium ions, as well as in hypoxia research to stimulate proteasome-dependent degradation of Hif-1α (Park, *et al*., 2000). Cadmium has no known useful role in higher organisms (Hogan *et al*., 2010), but a cadmium-dependent carbonic anhydrase has been found in some marine diatoms. The diatoms live in environments with very low zinc concentrations and cadmium performs the function normally carried out by zinc in other anhydrases(Lane and Morel, 2000).

2.4.4 Harmful effects of cadmium

The biogeochemistry of cadmium and its release to the environment has been the subject of review as an environmental hazard, as has the speciation of cadmium in the environment (Cullen and Maldonado, 2013). Human exposures to environmental cadmium are primarily the result of fossil fuel combustion, phosphate fertilizers, natural sources, iron and steel production, cement production and related activities, nonferrous metals production, and municipal solid waste incineration (Morrow, 2010).

There have been a few instances of general population toxicity as the result of long-term exposure to cadmium in contaminated food and water, and research is ongoing regarding oestrogen mimicry that may induce breast cancer (Mann, 2012). In the decades leading up to World War II, mining operations contaminated the Jinzū River in Japan with cadmium and traces of other toxic metals. As a consequence, cadmium accumulated in the rice crops growing along the riverbanks downstream of the mines. Some members of the local agricultural communities consuming the contaminated rice developed itai-itai disease and renal abnormalities, including

proteinuria and glucosuria (Nogawa *et al*., 2004). Cadmium is one of six substances banned by the European Union's Restriction on Hazardous Substances (RoHS) directive (IPCS, 1992). The International Agency for Research on Cancer has classified cadmium and cadmium compounds as carcinogenic to humans (IARC, 2009). Recent data from epidemiological studies suggest that intake of cadmium through diet associates to higher risk of endometrial, breast and prostate cancer as well as to osteoporosis in humans (Friberg, 1983). The highest concentration of cadmium has been found in the kidneys of humans (Perry and Vanderklein, 1996).

Tobacco smoking is the most important single source of cadmium exposure in the general population. It has been estimated that about 10% of the cadmium content of a cigarette is inhaled through smoking (Friberg, 1983). On average, smokers have 4–5 times higher blood cadmium concentrations and 2–3 times higher kidney cadmium concentrations than non-smokers. Despite the high cadmium content in cigarette smoke, there seems to be little exposure to cadmium from passive smoking. No significant effect on blood cadmium concentrations has been detected in children exposed to environmental tobacco smoke. Acute exposure to cadmium fumes may cause flu-like symptoms which can cause tracheo-bronchitis, pneumonitis, and pulmonary oedema. Inhaling cadmium-laden dust quickly leads to respiratory tract and kidney problems which can be fatal (often from renal failure). Cadmium exposure is a risk factor associated with early atherosclerosis and hypertension, which can both lead to cardiovascular disease (ATSDR, 2008).

The toxic effects of oral cadmium exposure have been well studied in animals, and a significant body of data from exposed humans has also been accumulated. In humans, most severe cases of oral cadmium toxicity have been associated with ingestion of foods or fluids contaminated by

storage in cadmium-plated containers. Death is usually due to excessive fluid loss from vomiting and diarrhoea. Lethal doses in humans have been reported to range from 1,500 to 8,900 mg, corresponding to doses of about 20 to 130 mg/kg in a 70-kg adult. Oral exposure to cadmium may result in adverse effects on a number of tissues, including kidney, liver, bone, testes, the immune system, and the cardiovascular system (Jarup, 1998). However, the levels of cadmium exposure through food, water, and air that are typical for most people are not of major health concern. For example, the intake of cadmium from the diet is usually about 0.0004 mg/kg/day, roughly ten times lower than the typical amount needed to cause kidney damage by this route Oral LD_{50} values for animals range from 225 to 890 mg/kg for elemental cadmium, 63 to 88 mg/kg for cadmium chloride, 72 mg/kg for cadmium oxide, and 590 to 1125 mg/kg for cadmium stearate (ATSDR, 2008).

Ingestion of any significant amount of cadmium causes immediate poisoning and damage to the liver and the kidneys (Maret and Jean, 2013). The kidney damage caused by cadmium poisoning is irreversible leading to kidney dysfunctions like failure to remove acids from the blood in proximal renal tubules. The proximal renal tubular dysfunction creates low phosphate levels in the blood (hypophosphatemia), causing muscle weakness and sometimes coma. The dysfunction also causes gout, a form of arthritis due to the accumulation of uric acid crystals in the joints because of high acidity of the blood (*hyperuricemia*). Another side effect is increased levels of chloride in the blood (*hyperchloremia*). The kidneys can reduce in size by up to 30%. Cadmium exposure is also associated with the development of kidney stones. Cadmium is transported in the blood by red blood cells and high-molecular-weight proteins such as albumin. Normal blood cadmium level in adults is < 1µg/dL. Although cadmium is widely distributed throughout the

body, most (50 to 70% of the body burden) accumulates in the kidneys and liver (Goyer, 1990). Cadmium burden, especially in the kidneys, tends to increase in a linear fashion with age up to about 50 or 60 years of age after which the kidney levels remain somewhat constant or slightly decline (Goyer, 1990). There is evidence that the placenta is a partial barrier to cadmium, and that the fetus is exposed to only small amounts of maternal cadmium (ATSDR, 1989).

2.4.4.1 Biochemical mechanisms of cadmium toxicity

Once cadmium is taken up by the blood, the majority of cadmium is transported and bound to proteins, such as albumin and metallothionein. When absorbed from the gastrointestinal tract, it first reaches the liver where it induces the production of metallothionein. After consecutive hepatocyte necrosis and apoptosis, cadmium-metallothionein complexes are washed into sinusoidal blood from where it enters the entero-hepatical cycle via secretion into the biliary tract in form of cadmium-glutathione conjugates. The conjugate is degraded by cadmium-cysteine complexes in the biliary tree and cadmium re-enters the small intestines (Zalups, 2003).

Cadmium has been showed to accumulate for a long period in the kidney (Orlowski and Piotrowski, 2003). The half-life period for cadmium is approximately 10 years. A life-long intake can therefore lead to a cadmium accumulation in the kidney, consequently resulting in tubule cell necrosis. The blood concentration of cadmium serves as a reliable indicator for a recent exposure, while the urinary concentration reflects past exposure, body burden and renal accumulation (Jin *et al*., 2002). Cadmium acts as a catalyst in forming reactive oxygen species. It increases lipid per oxidation, in addition it depletes antioxidants, glutathione and protein-bound sulfhydryl groups. It also promotes the production of inflammatory cytokines (Jarup, 1998).

Increased concentrations of urinary beta-2 microglobulin can be an early indicator of renal dysfunction in persons chronically exposed to low but excessive levels of environmental cadmium. The urinary beta-2 microglobulin test is an indirect method of measuring cadmium exposure. Under some circumstances, the US Occupational Health and Safety Administration require screening for renal damage in workers with long-term exposure to high levels of cadmium. Blood or urine cadmium concentrations provide a better index of excessive exposure in industrial situations or following acute poisoning, whereas organ tissue (lung, liver, and kidney) cadmium concentrations may be useful in fatalities resulting from either acute or chronic poisoning.

Cadmium concentrations in healthy persons without excessive cadmium exposure are generally less than 1 μg/L in either blood or urine. The American Conference of Industrial Hygienists (ACGIH) biological exposure indices for blood and urine cadmium levels are 5 μg/L and 5 μg/g creatinine, respectively, in random specimens. Persons who have sustained renal damage due to chronic cadmium exposure often have blood or urine cadmium levels in a range of 25-50 μg/L or 25-75 μg/g creatinine, respectively. These ranges are usually 100-300 μg/L and 100-400 μg/L, respectively, in survivors of acute poisoning and may be substantially higher in fatal cases (Basalt, 2008).

2.4.5 Treatment for cadmium toxicity

Cadmium poisoning is not reversible; it stays in the body system for a very long time and will be excreted along with metallothionein slowly. The following methods are used in detoxifying cadmium:

(a). Hemodialysis has been used before to get rid of cadmium that has not been absorbed from the bloodstream yet and sometimes EDTA chelation can help increase the productivity of the procedure (Longe, 2005). Vitamin C can bind cadmium and facilitate its removal. Sulfur compounds may also be helpful.

(b). Mineral balancing in reversing cadmium-induced pathology can be used through increasing biochemical energy production, which frees more energy for all normal metabolic activities. This is accomplished by precisely balancing the tissue electrolyte levels and ratios as revealed in an unwashed hair sample.

(c) Antagonists approach through administration of iron, zinc and copper. Zinc and calcium are cellular antagonists to cadmium. Selenium appears to reverse certain effects of cadmium toxicity. Diet plays an important role not only in avoiding sources of cadmium including refined and contaminated foods, but also to help balance the oxidation rate and provide adequate protein, minerals and vitamins.

(d) Reduce exposure e.g. occupational cadmium exposure, cigarette smoking and ingestion of cadmium-contaminated foods should be discontinued.

2.4.6 Risk mitigation recommendations for cadmium

To decrease global environmental cadmium emissions and reduce occupational and environmental exposure to cadmium and associated health effects, the following actions are needed:

i. Cigarette smoking in public places should be banned.

ii. Reducing as practicable emissions of cadmium, particularly into surface waters, from mining and smelting, waste incineration, application of sewage sludge to the land, and use of phosphate fertilizers and cadmium-containing manure. Develop techniques for the safe disposal of cadmium-containing wastes and effluents.

iii. Promote effective measures to increase recycling of cadmium and to restrict non-recyclable uses.

iv. Reduce cadmium exposure by, for instance, improving working conditions in the non-ferrous smelting industry and disseminating information on the proper use of fertilizers (which sometimes contain high levels of cadmium).

v. Raise global awareness on the importance of minimizing waste discharges of cadmium.

vi. Improving dietary intake of essential vitamins in high exposure populations.

2.5 Meat

Meat is a term applied to the edible portions of domestic mammals such as cattle, calves, sheep, lambs, and swine are referred to as beef, veal, mutton, and pork respectively. The term *meat* can be applied to the edible portions of poultry and wild birds and mammals (game) and to the portions of other animals such as crustaceans and reptiles that are eaten by humans (Microsoft Encarta, 2009). Humans are omnivorous (McArdle, 2013) and have hunted and killed animals

for meat since prehistoric times (Lawrie and Ledward, 2006). The advent of civilization allowed the domestication of animals such as chickens, sheep, pigs and cattle, and eventually their use in meat production on an industrial scale (Robert, 2010).

2.5.1 Nutritional importance of meat in human diet

Beef, mutton, fish and other meats when consumed in moderation and combined with whole grains vegetables and fruits offer more than just different flavours but improve the nutritional value of the meal. According to Bill, (2010) depriving the body of meat could cause health related problems.

Animal protein being a complete protein (Bastin, 2007) and therefore having a relatively higher biological value compared to other sources such as beans and whole wheat is vital in the diet of man (Ziegler, 1968). According to McAlpine (2011), iron deficiency anaemia is the most common nutritional deficiency in the world. Iron found in red meat is termed haem iron which is more easily used by the body than non-haem iron, the form of iron found in plants (Tremblay, 2011). Cross and Overby (1988) also stated that there is the need for meat protein in the diet of those people who suffer from marginal iron or calcium deficiency. The recommended daily protein intake of a person should be 1g per kg body weight and it is desirable that 50 % of this intake be animal proteins. The quality of a protein is a measure of its ability to satisfy human requirements for amino acids. Many animal sources have a Net Protein Utilization NPU (a measure of the usefulness of the protein to the body), of about 0.75 while that of most plant foods is 0.5 to 0.6. Meat is a relatively concentrated source of high quality protein with an NPU value of 0.75 to 0.8 (about 95 % digestible compared with 80 % to 90 % for many plant foods)

and it supplies a relative surplus of one essential amino acid, lysine, which is in relatively short supply in most cereals (FAO, 1992).

Meat and meat products are important sources of all the B-complex vitamins including thiamin riboflavin, niacin, biotin, vitamin B_6 and B_{12}, pantothenic acid and folic acid and higher intake of them is therefore recommended for patients at the convalescent stages (FAO, 1992). Beef and mutton are among the richest sources of iron and zinc, with a 100 g portion providing at least one quarter of daily adult requirement. Meat protein also appears to enhance the absorption of iron and zinc from plant foods (Williams, 2007). Meat can be broadly classified as 'red' or 'white' depending on the concentration of myoglobin in muscle fibre. When myoglobin is exposed to oxygen, reddish oxymyoglobin develops, making myoglobin-rich meat appear red. The redness of meat depends on species, animal age, and fibre type. Red meat contains more narrow muscle fibre that tend to operate over long periods without rest, while white meat contains more broad fibre that tend to work in short fast bursts. Generally, the meat of adult mammals such as cows, sheep, goats, and horses is considered red, while chicken and turkey breast meat is considered white.

2.5.2 Traditional livestock breeds used as food animals in Nigeria.

Livestock rearing has been on the increase in Nigeria. According to the Federal Ministry of Agriculture and Water Resources report (2008), 80% of goats, 70% of sheep and 80% of cattle in the country are produced in the northern region of the country, while 80% of pigs and 85% of poultry are produced in the south. The traditional system of management had remained the most practiced in the country for some 99.90% of goats, 99.50% of cattle, 99.84% of sheep, 96.76% of pigs and 86.17% of poultry.

2.5.2.1 Cattle

Nigeria has a cattle population of about 13.5 million which are reared under pastoral systems in villages. The breeds of cattle reared are predominantly Zebu, which also include are "Muturu", "Ndama", "Keteku Kuri", "Bunaji/White Fulani", "Sokoto Gudali", "Rahaji", "Wadara" and "Adamawa Gudali".

2.5.2.2 Sheep

Sheep are reared everywhere in Nigeria because they are seen as having secondary importance in relation to crops. There are generally considered to be four breeds or races of sheep native to Nigeria, the "Balami", "Uda", "Yankasa" and "West African dwarf".

2.5.2.3 Goats

Goat production has risen from 45.3 million to 52.5 million goats from 2001 to 2007. Breeds include "Sahalian Goat", "Sokoto Red Goat", "West African Dwarf Goat". The most common breed of goat reared in Nigeria is the "Red Sokoto/Kano Brown" produced in the North-West, North-East, and North-Central states, where all their grazing are done in the derived/savannah region and at maturity transported to the south where most of them are usually confined and fed with fresh forage (fodder) until they are sold for slaughter.

2.5.2.4 Camels

Camels were originally domesticated from Asia with two species *Camelus bactrianus* (two humped camel) and *Camelus dromedarius*, (one humped camel). Camels specialize in eating browse and can digest foliage from thorn trees and other armed plants that are virtually

unavailable to other domestic species. The population of camels 87,000 concentrated in the semi arid regions of Nigeria like Borno, Sokoto, Kebbi, Kano, Zamfara, just to mention a few, with an annual slaughter of 11,000 for meat, the textile industry, raw materials, recreation and prestige (Pwaveno and Arunsi, 2011).

2.5.3 Global meat consumption patterns and consumer health perceptions

Globally production and consumption of meat and other animal source foods (ASF) will continue to rise from 233 million metric tons in 2000 to 300 million in million metric tons 2020 (FAO, 2003). Although there is a great rise in global livestock production, the pattern of consumption is very uneven (Speedy, 2003), and is based largely on availability, price and tradition (Pearson and Dutson, 1990). In the US meat consumption is 124 kg/capita/year, compared to the global average of 38 kg/capita/year. The countries that consume the least amount of meat are in Africa and South Asia where consumption is between 3 and 5 kg/capita/year (Speedy, 2003). In Bangladesh, India and Sri Lanka, this is compensated for by higher fish (17.5 kg) and milk (47.5 kg and 35.9 kg) consumption respectively. In Ghana the per capita consumption of meat is 9.2 kg which is supplemented by a relatively higher intake of fish (26.2 kg/capita/year) (FAO, 2003). In Nigeria the per capita consumption of meat is 156 kg of beef, 72.8kg of other meats, 93.6 kg of fish (Akinleye, 2009).

Consumers have been increasingly concerned about food-risks and personal health, particularly hygiene and quality and require detectable indications such as health certificates at the market place or veterinary stamps at the butcher stage in the developed world (Zaibet *et al.*, 2007). In the minds of consumers, food safety risk also includes spoilage and residues such as hormones,

drugs and heavy metals (Brewer and Prestat, 2002). This has resulted in an increase in demand for safe and healthy foods.

2.5.4 Heavy metal residues in meat and meat products

The National Residue Survey Annual Report (NRSAR), (2007), described residues to include pesticides and veterinary drugs currently in use, or pesticides that are no longer registered for use, but are known to persist in the environment (e.g. some organochlorine chemicals). It also includes derivatives of chemicals, conversion products, metabolites, reaction products and impurities considered to be of toxicological significance. For purposes of setting maximum residual limit (MRL), the Australian Pesticides and Veterinary Medicine Authority (APVMA), (2000) defined residue as the chemical, its metabolites and related compounds to which the MRL applies. The MRL is the maximum concentration of a residue that is legally permitted or recognized as acceptable in or on a food, agricultural commodity or animal feed (NRSAR, 2007). Toxic compounds which may be found in meat and meat products can be traced to treatment of animals with drugs for therapeutic or nutritive purposes, pollution of the environment where pollutants are transferred into the animal by way of the alimentary tract, and uptake or formation of toxic compounds during processing (Cross and Overby, 1988). Agricultural compounds and veterinary drugs help keep animals and crops free from pests and diseases, but one consequence of this is that some traces of the chemical may remain in meat, fruits or vegetables at the time they are slaughtered or harvested (New Zealand Food Safety Authority, 2007).

Subramanyan, (2009) indicated, that animal feed can be contaminated with industrial pollutants, heavy metals, radionuclides, toxins from micro organisms, toxic substances 23 from plants

particularly fodder plants and residues of pesticides accumulated by the plants during their growth from chemicals persistent in the soil. It was also indicated that chemicals used to manage pests during crop production in the field and during storage of the harvested commodity are also sources of contamination of livestock feed and are likely to be deposited on fat and muscle tissue. Kan and Meijer (2007) indicated that feedstuffs may also contain veterinary drugs and certain contaminants, which besides impacting negatively on quantity and safety of feed, also tend to accumulate in the animal tissues and products which would subsequently impact on human health. However, Cross and Overby (1988) mentioned that contamination of muscle tissues by lead and cadmium are only slightly affected by the level of these elements in animal feed. Nonetheless, high levels of lead and cadmium in the feed resulted in elevated residues in liver and kidney. Voegborloh and Chirgawi, (2007) reported that vegetation and soils along major highways were polluted by heavy metals from exhaust fumes and tyre wear. This suggests that food vendoring and animals grazing along highways with heavy traffic could result in contamination with heavy metals. Hasyimah *et al* (2011) presented the assessment outcome of cadmium and lead levels in commercial fish sold between wet market and super markets in Klang valley, Malaysia. These toxic elemental contaminants caused unhealthy effects to fish and were transferred into human metabolism through consumption of contaminated fish that leads to serious deterioration of human health status (Zhou *et al*., 2008).

In Nigeria, chicken, chevron, mutton and beef are major sources of protein and are widely consumed. Akan *et al*., (2010) reported the concentration of heavy metals (Cu, Zn, Co, Mg, Fe, Cr, Cd, As, Ni and Pb) in liver, kidney, beef, mutton, goat and chicken from Kasuwan shanu market in Maiduguri Metropolis, Borno state, Nigeria, within the tolerance limits with the

exception of Cr and Pb which were higher than the permissible limits set by ANZFA (2001). Mariam *et al*., (2004) determined the level of selected minerals (arsenic, cadmium, lead, mercury and zinc) and some macro elements (calcium, sodium and potassium) in the lean and organs meat of beef, mutton and poultry. The levels of arsenic (40.80–52.44 ppm), lead (2.02–4.25 ppm) and mercury (31.47–78.96 ppm) were found higher than the permissible limits indicating contamination of the environment with heavy metals. Nwude *et al* (2010) also reported levels of Pb, Cd, Co, Zn, Cu and Fe determined in the muscle tissue of cattle at slaughtered with a peak of 0.005-3.90 mg/kg above permissible levels indicating an increasing level of pollution in the environment in which some animals which form part of human diet are constantly in contact with.

2.6 Risk Assessment of Heavy Metals

2.6.1 Theory of risk assessment

People are exposed to a variety of potentially harmful agents in the air they breathe, the liquids they drink, the food they eat, the surfaces they touch and the products they use. An important aspect of public health protection is the prevention or reduction of exposures to environmental agents that contribute, either directly or indirectly, to increased rates of premature death, disease, discomfort or disability (WHO, 2000).

Since 1970, the field of risk assessment has received widespread attention within both the scientific and regulatory communities (Paustenbach, 2002). Risk assessment is a conceptual framework that provides the mechanism for a structured review of information relevant to estimating health or environmental outcomes. In conducting risk assessments, the National

Academy of Sciences risk assessment paradigm has proven to be a useful tool (National Research Council, 1983). This paradigm divides the risk assessment process into four distinct steps namely hazard identification, dose-response assessment, exposure assessment, and risk characterization (Cirone and Duncan, 2000).

2.9.1.1 Hazard identification

The purpose of hazard identification is to evaluate the weight of evidence for adverse effects in humans based on assessment of all available data on toxicity and mode of action. It is designed to address primarily two questions:

(1) Whether an agent may pose a health hazard to human beings, and

(2) Under what circumstances an identified hazard may be expressed (Paustenbach, 2002).

Hazard identification is based on analyses of a variety of data that may range from observations in humans to analysis of structure-activity relationships. The result of the hazard identification exercise is a scientific judgment as to whether the chemical evaluated can, under given exposure conditions, cause an adverse health effect in humans. Generally, toxicity is observed in one or more target organ(s). Often, multiple end-points are observed following exposure to a given chemical. The critical effect, which is usually the first significant adverse effect that occurs with increasing dose, is determined.

2.9.1.2 Dose-response assessment

Dose-response assessment is the process of characterizing the relationship between the dose of an agent administered or received and the incidence of an adverse health effect. For most types of toxic effects (i.e. organ-specific, neurological/behavioral, immunological, non-genotoxic

carcinogenesis, reproductive or developmental), it is generally considered that there is a dose or concentration below which adverse effects will not occur (i.e. a threshold). For other types of toxic effects, it is assumed that there is some probability of harm at any level of exposure (i.e. that no threshold exists). At the present time, the latter assumption is generally applied primarily for mutagenesis and genotoxic carcinogenesis. If a threshold has been assumed, traditionally, a level of exposure below which it is believed that there are no adverse effects, based on a NOAEL/LOAEL (no/lowest-observed adverse effect level) and uncertainty factors, has been estimated. Alternatively, the magnitude by which the NOAEL/LOAEL exceeds the estimated exposure (i.e. the "margin of safety") is considered in light of various sources of uncertainty. In the past, this approach has often been described as a "safety evaluation". Therefore, the dose that can be considered as a first approximation of the threshold is critical. Increasingly, however, the "benchmark dose", a model-derived estimate (or its lower confidence limit) of a particular incidence level for the critical effect, is being proposed for use in quantitative assessment of the dose-response for such effects. There is no clear consensus on appropriate methodology for the risk assessment of chemicals for which the critical effect may not have a threshold (i.e. genotoxic carcinogens and germ cell mutagens). Indeed, a number of approaches based largely on characterization of dose-response have been adopted for assessment in such cases. Therefore, the critical data points are those that define the slope of the dose-response relationship (rather than the NOAEL, which is the first approximation of a threshold).

2.9.1.2 Exposure assessment

The third step in the process of risk assessment is the exposure assessment, which has the aim of determining the nature and extent of contact with chemical substances experienced or anticipated

under different conditions. Multiple approaches can be used to conduct exposure assessments. Generally, approaches include indirect and direct techniques, covering measurement of environmental concentrations and personal exposures, as well as biomarkers. Questionnaires and models are also often used. Exposure assessment requires the determination of the emissions, pathways and rates of movement of a substance and its transformation or degradation, in order to estimate the concentrations to which human populations or environmental spheres (water, soil and air) may be exposed. Depending on the purpose of an exposure assessment, the numerical output may be an estimate of the intensity, rate, duration or frequency of contact exposure or dose (resulting amount that actually crosses the boundary). Three main exposure routes are determined in exposure assessment: dermal, oral and respiratory. For risk assessments based on dose-response relationships, the output usually includes an estimate of dose. It is important to note that the internal dose, not the external exposure level, determines the toxicological outcome of a given exposure. The general equation of selected exposure route is the following:

$$ADD = \frac{C \times IR \times EF \times ED}{BW \times AT}$$

Where

ADD= (Lifetime) Average Daily Dose (mg/kg^{-1})

C= concentration in the media ($mg\ kg^{-1}$)

IR = ingestion rate ($kg\ day^{-1}$),

EF= exposure frequency ($days\ year^{-1}$),

ED= exposure duration (years),

BW= body weight (kg),

AT = average time (days).

The term ‘worst case exposure’ has historically meant the maximum possible exposure, or where everything that can plausibly happen to maximize exposure, happens. While in actuality, this worst case exposure may fall on the uppermost point of the population distribution, in most cases, it will be somewhat higher than the individual in the population with the highest exposure. The worst case represents a hypothetical individual and an extreme set of conditions; this will usually not be observed in an actual population (USEPA, 1992).

Therefore in most risk assessments the ‘weakest link’ is the exposure assessment (Bridges, 2003). On one hand the uncertainty of exposure assessment is caused by the calculation of residues in soil, water or air, which is often not a good indicator of bioavailability. The use of biomarkers may provide more information about the pollution (Kakkar and Jaffery, 2005), while on the other hand pollution often occurs in hotspots due to point sources and it is inadequate to assume that the whole population is exposed to the same, maybe average, contaminant level. By maintaining the spatial distribution of soil contaminant levels and receptors, it is possible, via the source-pathway-receptor paradigm to calculate more realistic contaminant intake and hence risks (Gay and Korre, 2006). Site-specific risk assessment is based on location specific exposure pathways and land-uses, hence get more realistic results, but often is limited to high-profile studies and large projects (Lester *et al*., 2007).

2.9.1.2 Risk Characterization

Risk characterization is the final step in risk assessment. It is designed to support risk managers by providing, in plain language, the essential scientific evidence and rationale about risk that they need for decision-making. In risk characterization, estimates of the risk to human health

under relevant exposure scenarios are provided. Thus, a risk characterization is an evaluation and integration of the available scientific evidence used to estimate the nature, importance, and often the magnitude of human and/or environmental risk, including attendant uncertainty, that can reasonably be estimated to result from exposure to a particular environmental agent under specific circumstances.

The term 'risk management' encompasses all of those activities required to reach decisions on whether an associated risk requires elimination or necessary reduction. Risk management strategies/or options can be broadly classified as regulatory, non-regulatory, economic, advisory or technological, which are not mutually exclusive. Key decision factors such as the size of the population, the resources, costs of meeting targets and the scientific quality of risk assessment and subsequent managerial decisions vary enormously from one decision context to another.

It is also recognized that risk management is a complex multidisciplinary procedure which is seldom codified or uniform, is frequently unstructured, but which respond to evolving can input from a wide variety of sources. Increasingly, risk perception and risk communication are recognized as important elements, which must also be considered for the broadest possible public acceptance of risk management decisions (WHO, 1999; Paustenbach, 2002).

2.6.2 Risk assessment of metals

Among other routes, food is one of the main sources of consumer exposure to heavy metals. Since dietary intake of metals may contribute to the development of various disorders, there is a necessity for monitoring of these substances in the human diet. To estimate the dietary intake of food contaminants, the different approaches can be utilized. The exposure estimation is a

complex process and no single approach is suited to all circumstances. The final choice of method to estimate heavy metal intake depends, among other things, on the intended goal, the availability of data, the nature of the chemicals, and so forth. In addition, it is important to note how detailed and precise the information concerning toxic elements intake needs to be. Considering that heavy metals are present in low concentrations in food samples, sensitive analytical techniques are required to measure their concentrations with appropriate accuracy. In most inorganic laboratories, spectrophotometric techniques are usually employed for the quantification of metals. Inorganic metals and metal compounds have unique characteristics that should be considered when assessing their risks. Metals are neither created nor destroyed by biological or chemical processes; they are transformed from one chemical form to another. Native (zero valences) forms of most metals and some metal compounds are not readily soluble, and as a result, toxicity tests based on soluble salts may overestimate the bioavailability and toxicity of these substances accumulations of essential metals (Fairbrother *et al.*, 2007).

The most important source for direct human exposure is the 'econosphere', which contains food and drinking water (Baker *et al.*, 2003). Trophic transfer can be an important route of exposure for metals, although bio magnification of inorganic forms of metals in food webs is generally not a concern in metals assessments. Whenever feasible, monitoring data from dietary intake studies should be compared with the acceptable or tolerable daily intake Acceptable daily intake (ADI), Tolerable daily intake (TDI), Provisional maximum tolerable daily intake (PTDI), Provisional tolerable monthly intake (PTWI), Provisional tolerable monthly intake (PTMI) recommended by the Joint FAO/WHO Expert Committee on Food Additives (JECFA), and other regulatory bodies (JECFA, 2005).

1. ADI (Acceptable Daily Intake):The ADI refers to substances that can be ingested daily without substantial health risks whereas the An estimate of the amount of a substance in food or drinking water, expressed on a body-weight basis, that can be ingested daily over a lifetime without appreciable risk (standard human = 60 kg). The ADI is listed in units of mg per kg of body weight.
2. TDI (Tolerable Daily Intake): The endpoint used for contaminants with no cumulative properties. Its value represents permissible human exposure as a result of the natural occurrence of the substance in food and in drinking-water. In the case of several heavy metals, which are able to accumulate in the body
3. PMTDI (Provisional Maximum Tolerable Daily Intake): The endpoint used for contaminants with no cumulative properties. Its value represents permissible human exposure as a result of the natural occurrence of the substance in food and in drinking-water. In the case of trace elements that are both essential nutrients and unavoidable constituents of food, a range is expressed, the lower value representing the level of essentiality and the upper value the PMTDI.
4. PTWI (Provisional Tolerable Weekly Intake): An endpoint used for food contaminants such as heavy metals with cumulative properties. Its value represents permissible human weekly exposure to those contaminants unavoidably associated with the consumption of otherwise wholesome and nutritious foods.
5. PTMI (Provisional Tolerable Monthly Intake): An endpoint used for a food contaminant with cumulative properties that has a very long half-life in the human body. Its value represents permissible human monthly exposure to a contaminant unavoidably associated with otherwise wholesome and nutritious foods.

6. (DIM) Daily Dietary Intake of Metals: The daily dietary intake of metals expresses the dietary availability of metals in a particular food. The DIM therefore, differs from the later in the sense that it gives an approximate available metal in food and essential in risk assessment of metals. The daily intake of heavy metals depends on both the concentration of heavy metals in food and the associated consumption data. Additionally, body weight can influence the tolerance of pollutants (Ying *et al*., 2014).
7. (EDIM) Estimated Daily Intake of Metals: The EDI was calculated to estimate the combined daily heavy metal loading into the body system of a specified body weight of a consumer. This gives the relative bioavailability of lead and cadmium in the meats of slaughtered animals. It assumes the magnitude of adverse effect that will be proportional to the sum of multiple metal exposures and does not take into cognizance the possible metabolic ejection of the metals but can easily tell the possible ingestion rate of a particular metal.

2.7 Principles of Atomic Absorption Spectrometry

Atomic absorption spectroscopy (AAS) is a spectroanalytical procedure for the quantitative determination of chemical elements employing the absorption of optical radiation (light) by free atoms in the gaseous state (Welz, and Sperling, 1999). In analytical chemistry the technique is used for determining the concentration of a particular element (the analyte) in a sample to be analyzed by measuring the absorbed radiation by the chemical element of interest. This is done by reading the spectra produced when the sample is excited by radiation. The atoms absorb ultraviolet or visible light and make transitions to higher energy levels. Atomic absorption methods measure the amount of energy in the form of photons of light that are absorbed by the

sample. A detector measures the wavelengths of light transmitted by the sample, and compares them to the wavelengths which originally passed through the sample. A signal processor then integrates the changes in wavelength absorbed, which appear in the readout as peaks of energy absorption at discrete wavelengths. The energy required for an electron to leave an atom is known as ionization energy and is specific to each chemical element. When an electron moves from one energy level to another within the atom, a photon is emitted with energy E (Becker *et al*., 1996)

Atoms of an element emit a characteristic spectral line. Every atom has its own distinct pattern of wavelengths at which it will absorb energy, due to the unique configuration of electrons in its outer shell. This enables the qualitative analysis of a sample. The concentration is calculated based on the Beer-Lambert law. Absorbance is directly proportional to the concentration of the analyte absorbed for the existing set of conditions. The concentration is usually determined from a calibration curve, obtained using standard samples or solutions of known concentration (Harnly, 1986). However, applying the Beer-Lambert law directly in AAS is difficult due to: variations in atomization efficiency from the sample matrix, non-uniformity of concentration and path length of analyte atoms (in graphite furnace AA). The chemical methods used are based on matter interactions, i.e. chemical reactions. Typically, the technique makes use of a flame to atomize the sample, but other atomizers, such as a graphite furnace, are also used. Three steps are involved in turning a liquid sample into an atomic gas:

- 1. Desolvation – the liquid solvent is evaporated, and the dry sample remains;
- 2. Vaporization – the solid sample vaporizes to a gas; and
- 3. Volatilization – the compounds that compose the sample are broken into free atoms.

To measure how much of a given element is present in a sample, one must first establish a basis for comparison using known quantities of that element to produce a calibration curve. To generate this curve, a specific wavelength is selected, and the detector is set to measure only the energy transmitted at that wavelength. As the concentration of the target atom in the sample increases, the absorption will also increase proportionally. A series of samples containing known concentrations of the compound of interest are analyzed, and the corresponding absorbance, which is the inverse percentage of light transmitted, is recorded. The measured absorption at each concentration is then plotted, so that a straight line can then be drawn between the resulting points. From this line, the concentration of the substance under investigation is extrapolated from the substance's absorbance. To generate this curve, a specific wavelength is selected, and the detector is set to measure only the energy transmitted at that wavelength. As the concentration of the target atom in the sample increases, the absorption will also increase proportionally. A series of samples containing known concentrations of the compound of interest are analyzed, and the corresponding absorbance, which is the inverse percentage of light transmitted, is recorded. The measured absorption at each concentration is then plotted, so that a straight line can then be drawn between the resulting points. From this line, the concentration of the substance under investigation is extrapolated from the substance's absorbance.

The use of special light sources and the selection of specific wavelengths allow for the quantitative determination of individual components in a multi-element mixture. The advantages of using atomic absorption spectroscopy are, greater sensitivity and detection limits than other methods and direct analysis of some types of liquid samples AAS can be used to determine over

70 different elements in solution or directly in solid samples employed in pharmacology, biophysics and toxicology research (Harnly, 1986; Skoog, 2007).

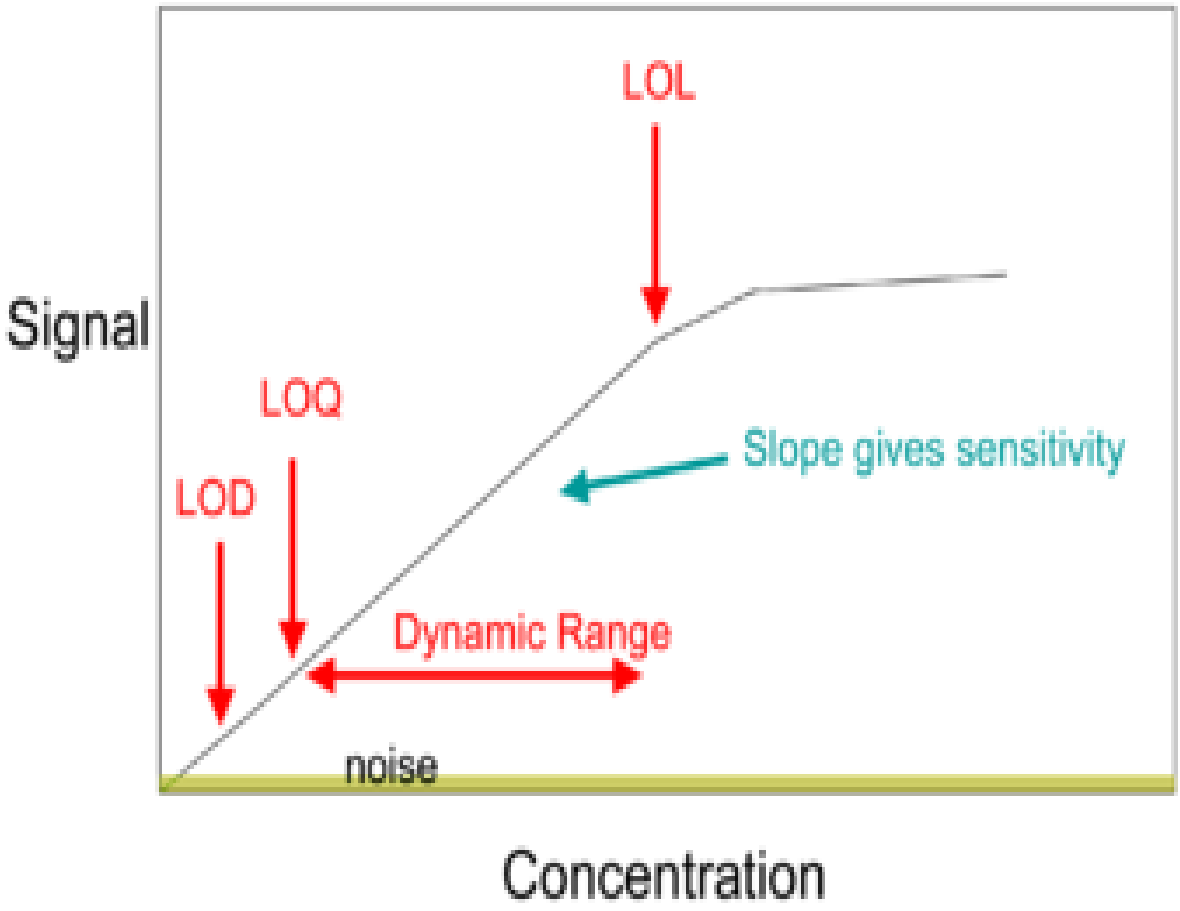


Fig 1.2 A calibration curve plot showing limit of detection (LOD), limit of quantification (LOQ), dynamic range, and limit of linearity (LOL) in an analyte during an Atomic Absorption Spectrometry technique.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area

The study area Gusau is the capital city of Zamfara State, Northwest Nigeria, and also a Local Government Area. It lies between latitude 12°10′N and longitude 6°42′E and has an area of 3,364 km² with general elevation of land 244 m to 366 m above sea level with a population of 383,162 at the 2006 census (National Population Commission, 2006).

3.2 Study Design

A cross-sectional study was carried out for a period of twelve weeks of sample collection and analyses. Meat samples were collected from 6 meat retail outlets in Gusau, viz; Danba, Tashan Lanlan, Old Market, New Market, Tudun Wada and Dagutu Road. The different beef, mutton and camel meat samples were distinguished with the help of a professional butcher in each of the retail outlets.

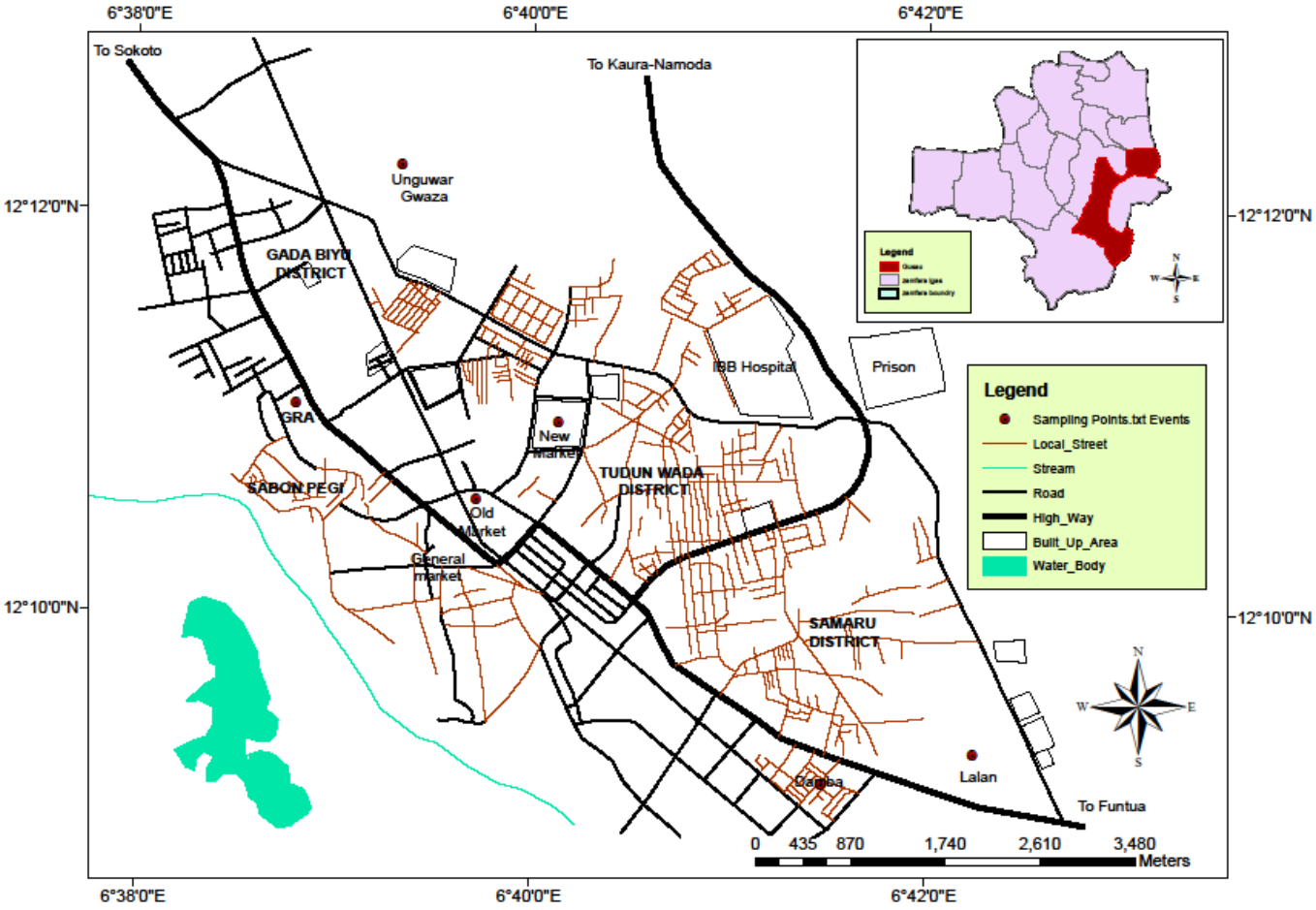


Fig 3.1; Map of Gusau Town showing different sampling areas.

Source: Google Earth.pro/fieldsurvey, 2014.

3.3 Sample Size

Sample size was determined using the formula by Thrusfield (1997).

$$n=zp^2 /d^2$$

Where

n= Sample size

z= standard normal deviation for 95% confidence interval (1.96)

p= expected prevalence (25% by (Akan *et al*., 2010)

d= desired absolute precision (0.05)

q= 1-p

$$n=\frac{1.96^2\times 0.25\times (1-0.25)}{0.25^2}$$

$$=288$$

300 samples were collected for this research to make up the number to a whole figure.

3.4 Sample Collection and Preservation

One hundred samples each of beef, mutton and camel meat making a total of three hundred meat samples were purchased from the different retail points in Gusau town using convenience sampling method. About 50 g of each meat sample was packed in polythene bags, properly labeled, and transported to Food Science Research Laboratory of Ahmadu Bello University Zaria, Kaduna State, Nigeria for drying, ash and sample digestion.

3.5 Processing of Samples

3.5.1 Digestion of samples (wet digestion)

Beef, mutton and camel meat and mutton samples were dried at 160 ^{o}C for two hours using an electric oven**.** Individual samples were crushed into fine powder using mortar and pestle, and 10 g of the fine powdered sample was weighed into porcelain crucible. The crucible and the fine powdered samples were ignited in a muffle furnace at 800 ^{o}C for six to eight hours. The samples were removed from the furnace and allowed to cool in desiccators. About 0.1 gram weight of the ash was placed inside a conical flask and 25 ml acid mixture of nitric, perchloric and sulphuric acid (32.5 ml of HNO_3; 3 ml of $HClO_4$ and 1 ml of H_2SO_4) was added and heated on sand bath electric hot plate (Model ARE Velp. Italy) for digestion, until a clear liquid solution is formed. The solution was filtered using Whatman 42 filter paper and the volume was made up to 25 cm^3 with de-ionized water and stored for atomic absorption analysis (AOAC, 1984).

3.5.2 Spectrophotometry techniques for lead and cadmium detection

The filtered samples were taken to the Multi-purpose Laboratory of the Department of Chemistry, Ahmadu Bello University, Zaria for lead and cadmium residues determination, under specified conditions according to the manufacturers recommendation (AA-240 FS VARIAN, Fast Sequential Atomic Absorption Spectrophotometer) (Szkoda and Żmudzki, 2005). Reagents blank were used, while taking the reading of the samples containing lead and cadmium. The sample solutions were aspirated into the flame and their absorbance reading recorded. Calibration curve for the absorbance readings of the solutions were plotted. The concentration of lead and cadmium were presented in parts per million (ppm) per litre and the values converted

appropriately to milligram of lead and cadmium per kilogram of meat sample (mg/kg) using the formula:

$$C\ (mg/kg) = \frac{(V \times SSC) - SB}{W}$$

Where

C= metal concentration

V= final volume of analyte

SSC= sample concentration (mg/kg)

SB= sample blank concentration (mg/kg)

W=sample weight (g)

3.6 Human Health Risks Assessment

The health risks assessment based on exposure of individuals (children and adults) to lead and cadmium from intake of beef, mutton and camel meat sold in Gusau, Zamfara State, Nigeria, and the risks to health assessed by comparing estimates of dietary exposure with the Tolerable Daily Intake (TDI) and Provisional Tolerable Weekly Intakes (PTWIs) recommended by the Joint FAO/WHO Expert Committee on Food Additives (JECFA), the values obtained were calculated as follows:

3.6.1 Average meat consumption.

As reported by Oforka *et al* (2012), dietary field survey study conducted, for the Nigerian populace on household daily mean consumption of various meats, at 47 g and 69 g of meat being consumed by children and adults respectively. The daily intake of heavy metals depends on both the concentration of heavy metals in food and the associated consumption data.

3.6.2 Daily dietary intake of metals (DIM)

The daily dietary intake of metals was calculated according to Ying *et al*. (2014) as follows:

$$DIM = \frac{C_{metal} \times D_{food\ intake}}{B_{average\ weight.}}$$

Where

C = concentration of metal

D = food intake

B = average body weight

Body weight = 70kg for adults and 20kg for children respectively.

3.6.3 Estimated daily intake of metals (EDIM)

The EDI for this study was calculated using this formula:

EDI (µg/kg/bw/day) = *DIM for lead* + *DIM for cadmium* (in test meat),

Where

EDI = Estimated daily intake

DIM = Daily dietary intake of metal.

3.6. 4 Hazard risk index (HRI)

The hazard risk index was calculated as the ratio of estimated exposure of test meat and oral reference dose of the heavy metals in question (Cui *et al*., 2004). Oral reference dose (*rfD*) is 0.035 mg/kg/day, for lead, and 0.001 mg/kg/day for cadmium (JECFA, 2005). Estimated exposure is obtained by dividing daily intake of heavy metals by their safe limits (0.05mg/kg for

lead and 0.01 mg/kg for cadmium) (WH0, 2011). An index of more than 1 is considered as not safe for human health (USEPA, 2011).

$$HRI = \frac{EE}{RfD}$$

Where

HRI = Hazard risk index

RfD = Oral reference dose

$$EE = \text{Estimated exposure} = \frac{DIM}{SL}$$

DIM = Daily dietary intake of metal

SL = Safe limit of heavy metals in food.

3.7 Questionnaire Administration

Two hundred structured questionnaires were administered to butchers and consumers in Gusau in Zamfara State. The information collected included age, sex, level of education and occupation, routine meat handling practices by butchers (hygienic practices), general knowledge and level of awareness of lead poisoning and finally meat consumption patterns, which included preparation, frequency of consumption and perceived safety of meat.

3.8 Data Analysis

Data generated were statistically tested using the Statistical Package for Social Science (SPSS) version 20.0 and presented as mean ± standard deviation. These results were also shown using tables, percentages histogram of the frequency distribution, a one-way sample ANOVA test was used to compare the mean concentrations between groups while Post-hoc test was further carried

to determine the difference within groups (multiple range test) with the value of $p < 0.05$ considered significant.

CHAPTER FOUR

RESULTS

4.1 Concentrations of Lead and Cadmium in Retail Meat Sold in Gusau, Zamfara State Nigeria.

Mean concentrations of lead in meat of animals sold in Gusau (table 4.1) showing the highest concentration of lead in camel meat at 98.38± 27.89 mg/kg followed by beef at 93.53± 29.17 mg/kg with the least being mutton at 71.76± 43.23 mg/kg.

Mean concentrations of cadmium in meat of animals sold in Gusau (table 4.2) showing the highest concentration of cadmium in beef at 21.43 ± 7.96 mg/kg , followed by camel meat at 18.30 ± 5.76mg/kg with the least being mutton at 5.88± 1.57 mg/kg

Table 4.1 Concentrations of Lead in Beef, Mutton and Camel meat sold in Gusau, Zamfara State.

Type of Meat	Number Collected	Range of lead Con. mg/kg	Mean lead Conc. mg/kg	P-value
Beef	**100**	**41.22-185.31**	**93.53 ± 29.17**	**0.000**
Mutton	**100**	**21.43-224.31**	**71.76 ± 43.23**	
Camel meat	**100**	**37.80-188.37**	**98.38 ± 27.89**	
TOTAL	**300**			

P- value > 0.05- Lead concentrations significantly differed between species.

Conc: Concentration

Table 4.1 Concentrations of Cadmium in Beef, Mutton and Camel meat sold in Gusau, Zamfara State.

Type of Meat	Number Collected	Range of Cadmium Conc. mg/kg	Mean Cadmium Conc. mg/kg	P-value
Beef	**100**	**10.72 - 35.13**	**21.43± 7.96**	**0.00**
Mutton	**100**	**0.00 - 21.59**	**5.88± 1.57**	
Camel meat	**100**	**5.60 - 31.60**	**18.30± 5.76**	
Total	**300**			

P- values > 0.05- Cadmium concentrations significantly differed between species.

Conc: Concentration

4.2 Risk Assessment of Lead and Cadmium for Children and Adults through Consumption of Beef, Mutton and Camel meat in Gusau, Zamfara State.

Figure 4.1 shows the daily dietary intake of lead (DIM) for children and adults Children had a significantly higher daily intake of lead from camel meat contributing the highest at 231.19 μg/day followed by beef at 219.79 μg/day and the least being mutton at 175.81μg/day, whereas adults daily intakes of lead from camel meat contributing the highest at 96.97 μg/day followed by beef at 92.19 μg/day and the least being mutton at 70.73μg/day.

Figure 4.2 shows the daily dietary intake of cadmium (DIM) for children and adults. Children had a significantly higher daily intake of cadmium from beef contributing the highest at 50.36 μg/day followed by camel meat at 43.01 μg/day and the least being mutton at 13.82 μg/day, whereas adults daily intakes of cadmium from beef contributing the highest at 21.12 μg/day followed by camel meat at 18.04 μg/day and the least being mutton at 5.79 μg/day.

Figure 4.3 shows estimated daily dietary intake (EDI) of lead and cadmium for children and adults with camel meat contributing a significant higher estimate of the combined metals for children at 274.2 μg/day above beef at 260.15μg/day, and mutton contributing 189.63 μg/day being the lowest, whereas for adults, camel meat and beef contributed a value of 114.01μg/day and 114.31μg/day with the least being mutton at 76.52 μg/day.

Figure 4.4 shows the hazard risk index (HRI) from consumption of the various meats with respect to lead and cadmium. The risk for children's consumption of beef is at 0.12 and 5.0, mutton is at 0.10 and 1.3 and camel meat at 0.13 and 4.3 whereas the risk for adults'

consumption of beef is beef 0.05 and 2.1, mutton 0.04 and 0.57 and camel meat 0.05 and 1.8 respectively.

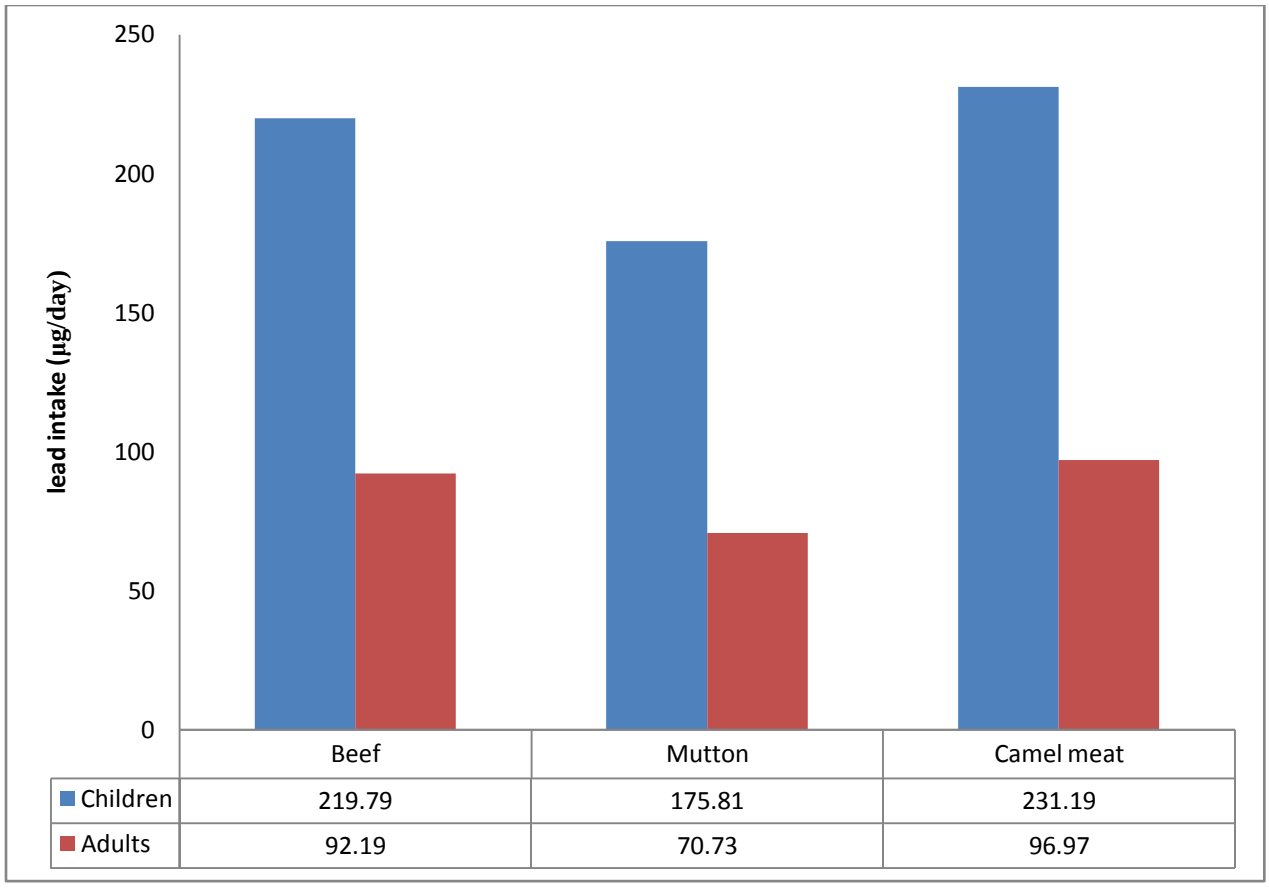


Figure 4.1 Daily Lead Intake by Children and Adults through Consumption of Beef, Mutton and Camel meat in Gusau, Zamfara State.

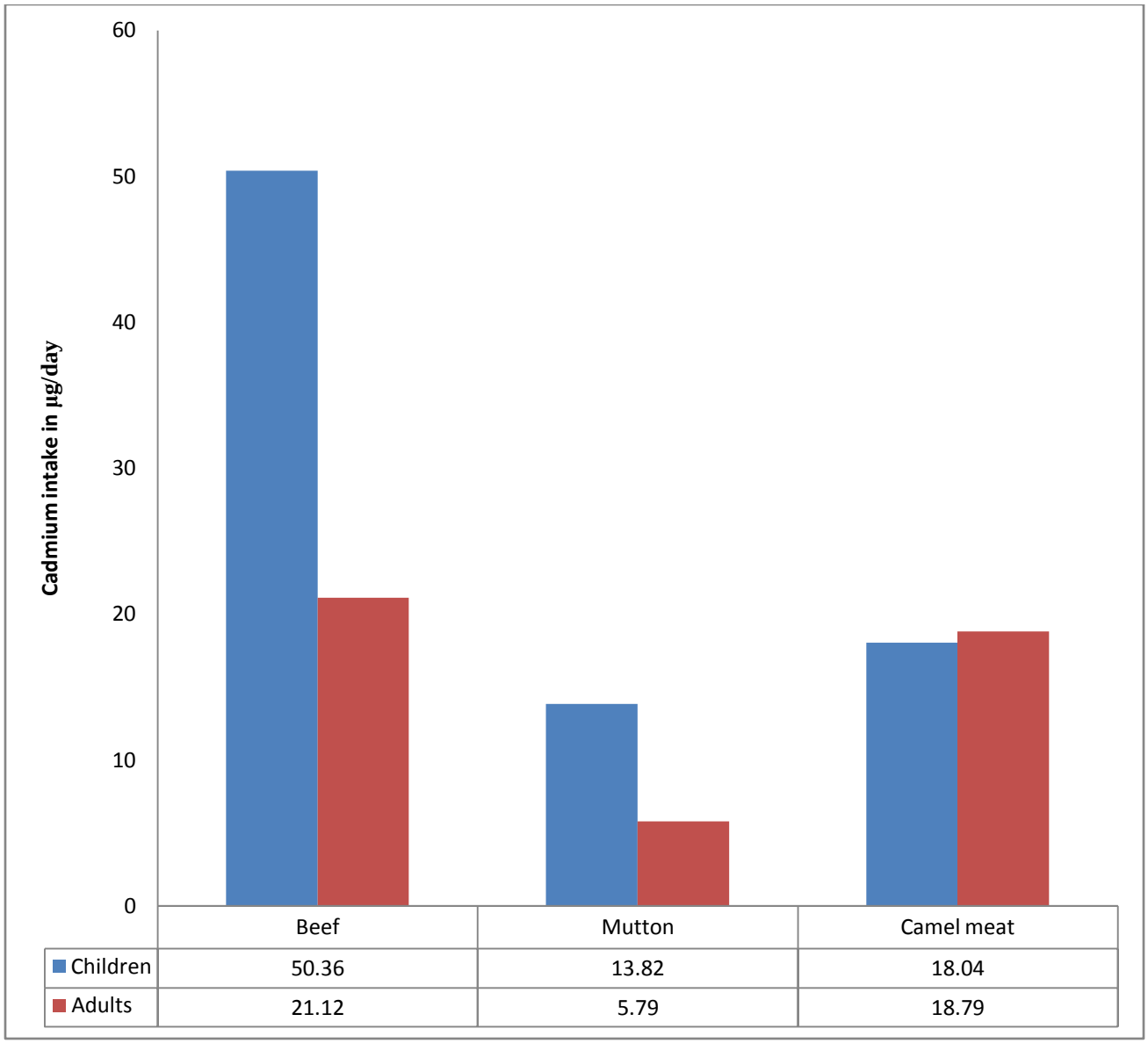


Figure 4.2 Daily Cadmium Intake by Children and Adults through Consumption of Beef, Mutton and Camel meat in Gusau, Zamfara State.

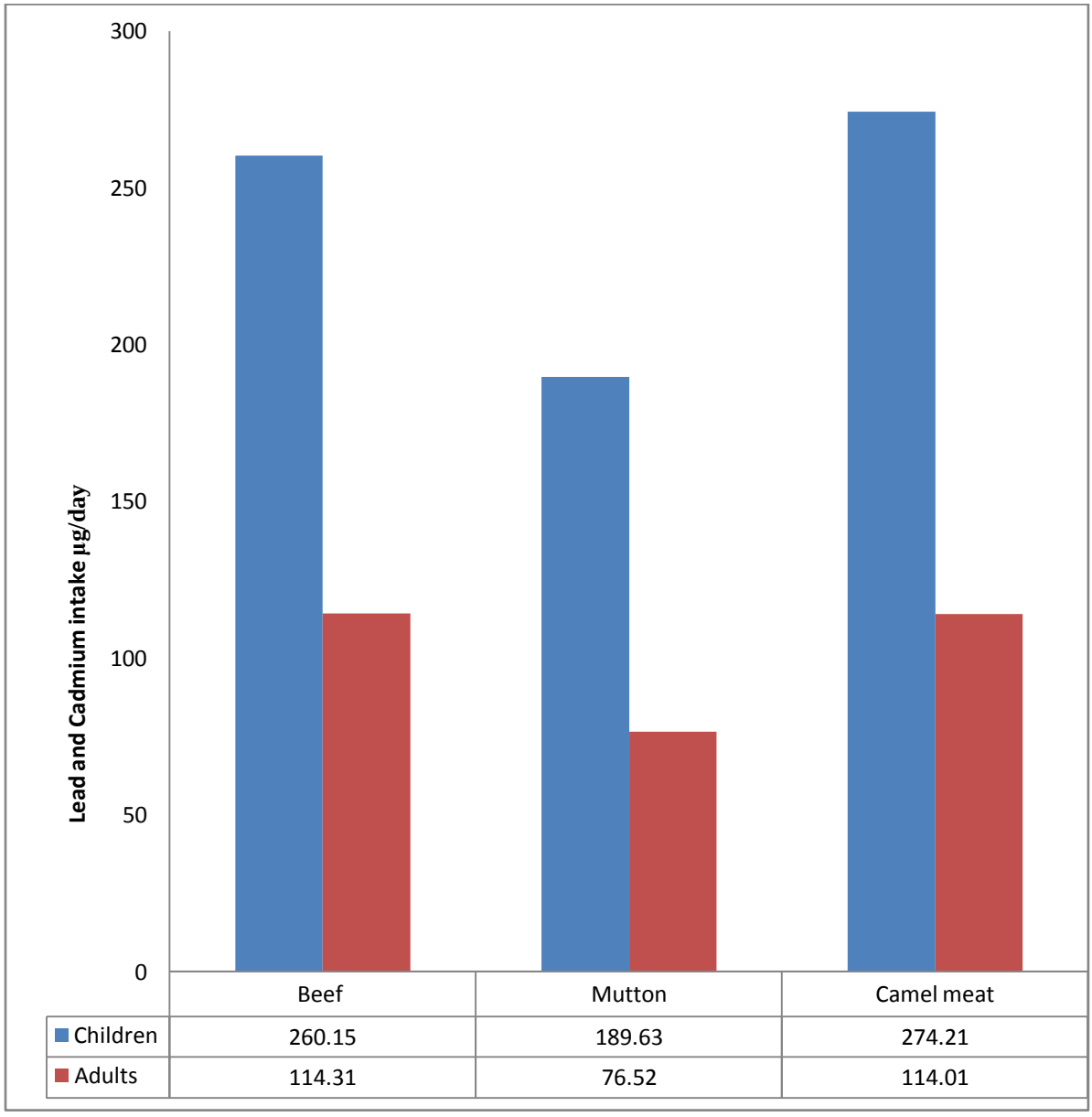


Figure 4.3 Estimated Daily Lead and Cadmium Intake by Children and Adults through Consumption of Beef, Mutton and Camel meat in Gusau, Zamfara State.

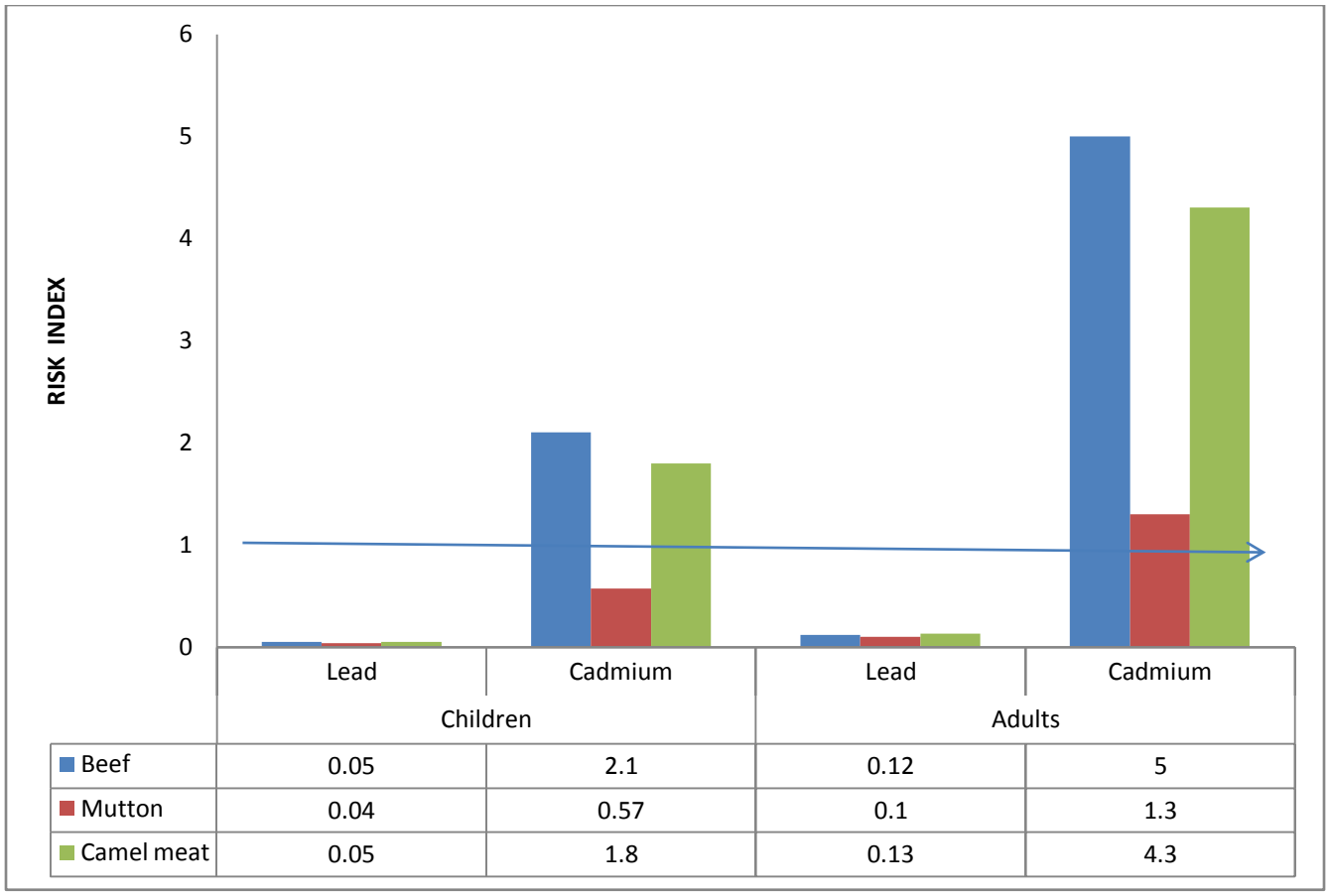


Figure 4.4 Hazard Risk Index (HRI) of Lead and Cadmium for Children and Adults through the Consumption of Beef, Mutton and Camel meat in Gusau, Zamfara State.

4.3 Responses from Questionnaire Based Survey in Gusau, Zamfara State.

Table 4.3 shows demographic data of the respondents to the administered questionnaires. Information regarding age, sex, level of education and occupation were collected and presented.

Results obtained on routine meat handling practices by butchers are shown in Table 4.4. Butchers responses included, how long they had been butchering/selling meat, type of meat commonly sold, patronage by consumers, knowledge regarding source of animals for slaughter and hygienic practices such as means of transporting, packaging and cleaning of the meat sold in case it came in contact with dirt.

Table 4.5 shows responses on awareness of heavy metal poisoning. Responses included knowledge about lead poisoning occurring in Zamfara State, sources of information, possible sources of contamination and the individuals who were more susceptible.

Table 4.6 shows respondents consumption choices with regard to the type of meat sold in retail outlets in Gusau town, preferred form of preparation of the meat, frequency of consumption and knowledge regarding safety of meat consumed.

Table 4.3 Demographic Data of Respondents on The Awareness of Heavy Metal Poisoning in Gusau, Zamfara State.

Demographic Data	No of Respondents	(%)
Sex		
Male	**117**	**58.5**
Female	**83**	**41.5**
Age		
< 15	**15**	**7.5**
16-30	**55**	**27.5**
31-45	**72**	**36.0**
>45	**58**	**29.0**
Level of Education		
No formal education	**40**	**20**
Quranic education	**46**	**23**
Primary education	**19**	**9.5**
Secondary education	**29**	**14.5**
Tertiary/higher education	**66**	**23.0**
Occupation		
Farmer	**18**	**9.0**
Civil servant	**52**	**26**
Butcher	**60**	**30**
Business man/woman	**33**	**16.5**
Miner	**12**	**6.0**
Students	**9**	**4.5**
Category of Respondents		
Butcher	**60**	**30.0**
Consumer	**140**	**70.0**
Total no of respondents	**200**	**100**

Table 4.4 Butchers/ Meat Sellers Responses to some Routine Handling Activities of Meat Sold in Gusau, Zamfara State

Questions	No of Respondents		Frequency (%)
Type of meat sold			
Beef	**28**		**46.5**
Mutton	**20**		**32.5**
Camel meat	**12**		**21.0**
Source of animals			
Zamfara	**22**		**36.0**
Other states	**33**		**55.0**
Outside Nigeria	**5**		**9.0**
Means of transportation of fresh meat			
Cars	**37**		**61.0**
Motorcycles	**11**		**29.0**
Bicycles	**6**		**10.0**
Means of packaging fresh meat for slaughter			
Sacks	**53**		**89.0**
	Yes (%)	**No (%)**	**No of respondents**
If they wash meat before selling	**4(6.0)**	**53(94.0)**	**60**
Frequency of washing			
Occasionally	**3 (75.0)**		**3**
Source of water			
(tap, well, borehole)	**4 (100)**		
No of patronage			
21-50	**14**		**36.0**
51-100	**38**		**64.0**
Above 100	**8**		**9.0**
Total	**60**		**100**

Table 4.5 Awareness and Knowledge of Respondents on Heavy Metal Poisoning in Gusau, Zamafara State.

Questions	Responses	No of Respondents	(%)
If they have heard about heavy metal poisoning**?**	**Yes**	**191**	**95.5**
	No	**9**	**4.5**
Which metal was implicated ?	**Lead**	**200**	**100**
How they heard about it?			
	Television	**30**	**15**
	Radio	**140**	**70**
	News paper	**12**	**6**
	Was told by someon	**18**	**9**
Where did the poisoning occur?			
	Gusau	**45**	**22.5**
	Other L.G.A.'s	**145**	**73.5**
If lead poisoning is a problem?			
	Yes	**199**	**99.5**
Where the problem could be coming from?			
	Mining	**134**	**67**
	Agric practices	**29**	**14.5**
	Other activities	**37**	**18.5**
If any family member had suffered from lead poisoning	**No**		**100**
Sources of lead			
	Environment	**135**	**62.5**
	Food	**65**	**32.5**
Susceptibility to lead poisoning			
	Children	**100**	**50**
	Adults	**40**	**20**
	The elderly	**22**	**11**
	Everybody	**38**	**19**
Total		**200**	**100%**

Table 4.6 Consumers Response to Meat Consumption Patterns and Knowledge on Possible Contamination of Meat by Heavy Metals

Questions	No of Respondents	(%)
Favorite meat of choice		
Beef	**100**	**50.0**
Mutton	**40**	**20.0**
Camel meat	**22**	**11.0**
Other types	**38**	**19.0**
What form they preferred the meat		
Boiled	**80**	**40.0**
Roasted	**52**	**26.0**
Fried	**68**	**34.0**
Frequency of consumption		
Daily	**147**	**73.5**
Occasionally	**53**	**26.5**
If meat can be contaminated with heavy metals		
Yes	**18**	**9.0**
No	**30**	**15.0**
Maybe	**152**	**76.0**
Possible routes of contamination		
Consumption of contaminated water and feed	**200**	**100**
Total	**200**	**100**

CHAPTER FIVE

DISCUSSION

The high concentrations of lead in beef, mutton, and camel meat determined in this study were significantly higher than international permissible limits. The consumption of these meats is of public health importance because lead is a toxic metal with cumulative toxicant effects (Fewtrell *et al*., 2003). The values obtained in this study were higher than 0.05 mg/kg recommended by the JECFA (Joint FAO/WHO Expert Committee on Food Additives, 2010): European Commission on Food Contaminants (2007): 0.1mg/kg of the National Standard of the Peoples Republic of China (2010) and were over a thousand times higher than all these permissible limits. The concentrations of lead residues in the various meat types were also higher than one reported by Nwude *et al*, (2010) of beef sampled from South Eastern Nigeria; Akan *et al*, (2010) from beef, mutton, caprine and chicken meat from Kasuwan Shanu Market in Maiduguri Metropolis, Borno State; Bala *et al*, (2012) from liver and kidneys of cattle slaughtered in Sokoto abattoir and Abubakar (2013) from animals slaughtered in Gusau.

Camel meat had the highest concentration of lead. Abubakar (2013), also reported similar findings in Gusau as well as Snezana and Jordan, (2010) in a study of heavy metals in cattle reared in the vicinity of a metallurgic industry in Probistip, Mecedonia. Camels are more likely to accumulate more lead because they are usually larger in size and consume more food, and are also older at slaughter when compared to other animals used for food. Abubakar (2013), reported that for animals slaughtered in Gusau Abattoir, cattle, sheep and goats were slaughtered at less than four years of age, while camels were about ten years of age at time of slaughter. These results agree with findings by Doriya *et al* (2006) where it was noted that animals with longer life spans have higher concentrations of this metal because lead is a bio-accumulative

heavy metal. Animals used for food serve as bio- indicators of environmental contamination with heavy metals (Akinola and Ekiyoyo, 2006; Miranda *et al*., 2009). The body burden of heavy metals in animals commonly consumed for food may reflect the locality's heavy metal status, as indiscriminate mining activities are commonly practiced in Zamfara with indications of opportunities for continuous exposures to lead and other contaminants in all aspects of daily lives. High lead forage content can lead to higher levels of intake by grazing animals, therefore toxicological risk of transfer from forage to grazing animals and subsequently to humans cannot be ruled out. Udiba *et al*. (2013) reported lead levels ranging between 5.59 -1312.73 mg/kg in forage grasses in a mining village in Zamfara. Transfer of lead to cattle through consumption of contaminated plants has been corroborated in literature (Swarup *et al*., 2005). High lead levels of 60,000 - 100,000 mg/kg before soil remediation exercises and 81.65 - 684.27 mg/kg after remediation have also been reported by environmental monitoring teams in Zamfara State, which were far above the USEPA 400 mg/kg guideline set for soil samples in residential areas, therefore increasing the risk of lead poisoning through the food chain increases as soil lead levels increases above this concentration. Consumption of meat from animals contaminated with lead constitutes serious public health risk because lead in forage settles in the stomach of animals particularly cattle, where stomach acids gradually change lead into poisonous salts like lead sulphate, ($PbSO_4$), lead dichloride ($PbCl_2$) (inorganic lead compounds) (Drage, 2009). A lot of these animals also come from outside the country especially through Northern States that share borders with Niger (in the North-west) Cameroon, and Chad Republic (in the North-east) also showing lead contamination is a problem in Sub-Saharan Africa (personal interview with butchers). There is no exposure limit for which lead is said to be safe limit.

The results for cadmium concentrations in this study were also far above recommended levels set by various food safety regulating bodies. Ingestion of any significant amount of cadmium causes immediate poisoning (Maret and Jean-Marc, 2013), although cadmium levels were about six times lower than lead levels seen in the meat samples, recent data indicate that adverse health effects of cadmium exposure may occur at lower exposure levels than previously anticipated with the margin being very narrow for large population groups (British Medical Bulletin, 2014). The cadmium values obtained in this study were higher than levels of 0.01mg/kg recommended by FAO, (2003), 0.05mg/kg recommended by the JECFA (2010) for food, 0.01mg/kg, set by the European Commission, (2007), and were higher than several levels reported by other workers in Nigeria; 1.26 mg/kg in goat meat consumed in Nsukka, by Okoye and Ugwu, (2010), 0.34 mg/kg in meat of animals consumed in Maiduguri (Akan *et al*., 2010), 1.70 mg/kg and 1.10 mg/kg reported by Bala *et al*., (2012) from liver and kidneys of cattle slaughtered in Sokoto, 4.60 mg/kg in chicken and turkey meat consumed in Delta State, 0.161 mg/kg reported by Miranda *et al.* (2005) on calves from polluted industrialized areas of Northern Spain and 0.096 mg/kg for those in rural areas. All the mean values were also higher than 0.038 mg/kg reported by Falanysz *et al.* (1994) 0.058 mg/kg on liver of poultry from polluted area in Poland. Cadmium is used in a wide spectrum of applications including alloys, pigments, metal coatings, batteries and in the electronic industry. It is also a contaminant in chemical fertilizer, manure and sewage sludge (Ademoroti, 1996; Ladigbolu and Balogun, 2011). Its high ability to migrate from the soil to plants (Peterson and Alloway, 1979) may be the main cause of animal exposure to this element. The neighboring states of Katsina, Sokoto, Kebbi, are border states of the country and well known routes for import of animals which end up being slaughtered in abattoirs all over Nigeria including Gusau are agricultural areas (personal interview with butchers), where

cadmium in the soil can originate mostly from chemical substances and fertilizer used in agricultural practices. Other possible sources of contamination may include exhaust emissions from motor vehicles, emissions from local industrial premises, dumping of industrial wastes, effluents and agricultural activities, which may contaminate soil, plants, water, and air (Bala *et al*., 2012). It is also by-product in the production of zinc and lead (Su and Wong, 2003), Zamfara being a mining region contains many areas with significant concentrations of heavy metals in the soil and rocks (MSF, 2012).

The dietary intake of heavy metals from food sources is crucial in evaluating the safety of food for consumers (Oforka *et al*., 2012). The mean daily intake of lead in this study in children was almost seven times higher than the tolerable daily intake (TDI) of lead set by the European Food Safety Authority (EFSA), (2013), for lead sources at 36 μg for a 0 - 6 months-old infant and 54 μg for a 6 months to 2 year-old child. Based on the assumption that food contributes about 50 % of the total daily intake of lead, the TDI of lead from dietary sources would range from 18 to 27 μg. Based on the CDC's ―Blood Lead Level of concern', and the U.S. Food and Drug Administration (FDA) provisional total tolerable intake level (PTTIL) for lead at 6 μg/day for small children (under the age of six years). The DI was also higher than 4.47 μg/day reported by Oforka *et al*., (2012), and daily intakes of lead from vegetables grown in Zamfara reported by Galadima *et al*., (2012). The daily intake of lead by children in this study was higher than the Provisional Tolerable Weekly Intake (PWTI), of 25 μg/kg/bw/week for children (WHO, 2000). From the foregoing, the implication of this for a child is that the Committee on Toxicity of Chemicals in Food, Consumer Products and the Environment (COT) estimated that in infants and young children the intake of dietary lead at the PTWI would likely result in an approximate 36

μg/L increase in the blood lead (B-Pb) and this in turn will cause a deficit of 0.36 of IQ. This estimation relied on the Joint WHO/FAO Expert Committee on Food Additives (JECFA), correlation between dietary intake and B-Pb increase (i.e.1 μg/kg/bw/day results in 10 μg/L B-Pb increase), and it was based on the assumption that each 100 μg/L increase in B-Pb causes the IQ score to decrease by 1 to 5 points (ATSDR, 2007). The dietary intake of lead for adults in this study was higher than the tolerable daily intake of 75 μg/kg bw per day (FDA, 2006), and also higher than an average of 59.14 μg/day reported by Oforka *et al*., (2012) for pregnant women, lactating mothers, both adult men and women, also higher than 28 μg /wk reported for meat, fish and milk consumed in Brazil (Santos *et al*., 2004). The values also exceeded values of 57.3 ug/day in fish and seafood consumed in Kualar Lumpur as reported by Zawiah and Rosmiza (1995). The implication for adults being that lead would become toxic if it is consumed in the amount which exceeds the threshold and can cause acute and chronic poisoning symptoms (Jarup, 2003). Children are particularly vulnerable to lead being able to absorb up to 50% via the gastrointestinal tract while adults take up 10–15 % of lead in ingested food, Lead in blood is bound to erythrocytes, and elimination is slow and principally via urine. In adults, inorganic lead does not penetrate the blood–brain barrier, whereas this barrier is less developed in children. The high gastrointestinal uptake and the permeable blood–brain barrier make children especially susceptible to lead exposure and subsequent brain damage (ATSDR, 2006).

The mean daily intake (DI) of cadmium for children in this study is over a hundred times higher than the tolerable daily intake (TDI) of 0.5 μg/kg/bw/day set by the Dutch Institute of Food Safety. The DI values were higher than a value 2.1 μg/day of cadmium from consumption of meat, fish and milk consumed in Dar-es-Salaam Tanzania (Ngassapa *et al*., 2010) and also

higher than long term dietary intake of 0.32 µg/kg bw/day for 1-6 year-old children in The Netherlands (Winter *et al*., 2003). The dietary intake of cadmium for adults was higher than the tolerable daily intake of 1.0 µg/kg bw/ day, set by World Health Organization, the Food and Agriculture Organization of the United Nations, (2003), and United States Environmental Protection Agency, The daily dietary intake of cadmium for both children and adults was higher than the provisional tolerable weekly intake (PTWI) of 7.0 µg/kg bw/ day (JECFA, 2003). Dietary cadmium intake is log-normally distributed; therefore, a small increase in the population's average daily intake of cadmium will result in a much larger increase in the fraction of the population having the highest intake. An increase in the median daily intake by a factor of 2 (i.e. from 15 to 30 µg/day) would correspond to an increase in the 95th percentile from about 20 to 60 µg/day (Jarup *et al*., 1998). These values are based on the chronic effects of cadmium on kidney function. The public health implication for consumers is that cadmium derives its toxicological properties from its chemical similarity to zinc, an essential micronutrient for plants, animals and humans. It may actually displace zinc in some of its important enzymatic and organ functions interfering with these functions or preventing them from being completed. It is bio-persistent and tends to bio-accumulate. Once absorbed by an organism, it remains in the body for many years having a half-life for human kidney and liver at an estimated 6-38 years and 4-19 years, respectively. Cadmium is very slowly excreted (about 0.007 % of the body burden daily) (Baars *et al*., 2001).

The estimated daily intake (EDI) of lead and cadmium shown in this study summarizes the results of the actual combined exposure assessment for adults and children to heavy metals through consumption of any of the tested meat. The EDIs were higher than the oral reference

doses (RfD) of these metals, respectively while EDIs for children were higher than those for adults. Recent studies indicated that multiple-toxicant exposures can either exacerbate or counteract health effects of individual toxicants (ATSDR, 2004). At present there is no toxicological profile which shows the effect of lead and cadmium mixtures. However, synergistic toxicological effects on neurological development in early childhood have been found following lead and manganese coexposures (Henn *et al*., 2012). Other synergistic interactions such as lead–arsenic and lead–methylmercury have also been reported (ATSDR, 2004). Yuijing *et al*., (2005) showed that soil contamination with metal mixtures caused significant renal dysfunction of the local residents living in the contaminated area, and the dose–response curve was somewhat altered by the mixed contamination of cadmium and lead as well as the intake of other minerals. Perhaps such toxic synergism exists between lead and cadmium.

A hazard risk index (HRI) value greater of any food that is greater than 1 would indicate that a potential health risk may exist for consumers of such food. The values obtained from this study showed that there was higher risk for the general population consuming cadmium from meat than lead, although children were at a greater risk of consuming cadmium than adults. The Agency for Toxic Substances & Disease Registry (ATSDR) recognizes that due to the unique vulnerabilities of infants and children, they demand special emphasis in communities faced with contamination in their environment as is the case with Zamfara State, Nigeria. Children are usually at greater risk than adults from certain types of exposures to hazardous substances, because their lower body weight and higher intake rate results in a greater dose of hazardous substance per unit of body weight also the developing body systems of children can sustain permanent damage if toxic exposures occur during critical growth stages (EFSA, 2009). Mutton consumed in Gusau is safer

when compared to beef and camel meat in terms of lead intake because it had a hazard risk index of less than one. This simply means that the inhabitants of Gusau are highly exposed to health risk associated with cadmium to the greater extents. The results obtained in this study show that the high levels of these metals determined in the meat samples impair the quality of meat obtained for consumption in Gusau.

This survey showed that majority of respondents both butchers and consumers were aware of heavy metal poisoning especially lead poisoning and regard it as a serious public health problem with everybody being at risk especially children. Majority believe mining continues to be a source of contamination to the environment. There is little or no enforcement of minimum standard for heavy metal contents of domestic environments in Nigeria despite the health implications of these exposures. Meat from different ruminant animals are marketed and consumed in appreciable quantities on daily basis in Gusau, with respondents not being sure about the wholesomeness of the meat with regards to lead, cadmium or other heavy metals. There was general agreement on the need for the government to do more to increase awareness of lead exposure while putting effective control measures in place to check illegal mining and other sources of harmful substances that may be found in the environment.

CHAPTER SIX

CONCLUSIONS AND RECOMENDATION

6.1 Conclusions

This study has established high levels of lead and cadmium concentrations in beef, mutton, and camel meat sold and consumed in Gausau, Zamfara State, Nigeria with levels above the recommended values established by different food regulatory agencies. Camel meat had the highest level of lead (98.37 ±27.89 mg/kg), while beef had the highest level of cadmium (21.43 ± 7.96 mg/kg). Lead levels were over a hundred times, while cadmium levels were about forty two times higher than the permissible limits. The body burden of heavy metals in animals commonly consumed for food reflects the locality's heavy metal status, as they serve as bio- indicators or sentinels of environmental contamination with heavy metals.

The daily intake (μg/kg/bw/day) of lead for children consuming camel meat (231.19 μg), beef (219.79 μg) or mutton (175.81μg), is about seventy times higher than the tolerable daily intake (TDI) of 6ug/day of lead set by the European Food Safety Authority (EFSA) while that for adults consuming camel meat (96.97μg), beef (92.19 μg), or mutton (70.73 μg), is higher than the value of 75 μg/day set by the Food and Drug Authority (FDA). The daily intake of cadmium of this study for children consuming beef (50.36 μg), camel meat (50.36 μg), or mutton (13.82μg), is over a hundred times higher than the tolerable daily intake (TDI) of 0 .5 μg/kg/bw/day while that for adults consuming beef (21.12 μg), camel meat (18.04 μg) or mutton (6.79 μg), is higher than the tolerable daily intake of 1.0 μg/kg bw/day set by the above named authorities. In this study, the estimated daily intake (EDI) (μg/kg/bw/day) of lead and cadmium for children from consuming camel meat was (274.21 μg), beef (260.15 μg), or mutton (189.69 μg), whereas for

adults either consuming camel meat was (114.31 μg), beef (114.01 μg), or mutton (76.52 μg). This is an indication that multiple-toxicant exposures exist for residents in Gusau. Hazard Risk Index (HRI) for both children and adults showed that children had a higher risk of consuming cadmium from beef (5), mutton (1.3) or camel meat (4.3), the risk for adults' consumption of cadmium from beef was (2.1), mutton (0.57) or camel meat (1.8) respectively. Long term consumption of these meats may bear high risk of heavy metal exposure to the consumers. Majority of respondents were aware of heavy metal poisoning especially lead poisoning and regard it as a serious public health problem.

6.2 Recommendations

Heavy metal toxicity is a growing concern and often an unknown root cause of a number of serious health issues, while food intake results in long-term low level body accumulation of heavy metals and the detrimental impact becomes apparent only after several years of exposure. Therefore in view of these, the following recommendations are made:

1. Environmental remediation and impact assessment should be conducted by the Government with regular monitoring to determine the level of contamination of soil, water, forage and crops by heavy metals in vicinities where animals are reared for human consumption as well as advocating for safer mining practices.

2. Although some residents in Gusau were aware of lead poisoning, there is the need to intensify efforts for continuous medical care including chelation therapy and health education.

3. The National Agency for Food and Drug Administration Control (NAFDAC), Standard Organization of Nigeria (SON) and other relevant Agencies should carry out a full mandate on heavy metals along the food chain to ensure the safety of food in Nigeria.

4. Further study on heavy metals and risk assessment for consuming other local food items should be carried with the data obtained used out to apply to public health data and information from other health studies (including epidemiological data), that consider how issues are reported and approached when it comes to addressing variability and uncertainties associated with heavy metals.

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APPENDIX 1

Questionnaire Survey on public awareness of heavy metal poisoning in Gusau Zamfara state.

DEPARTMENT OF PUBLIC HEALTH AND PREVENTIVE MEDICINE,
FACULTY OF VETERINARY MEDICINE.
AHMADU BELLO UNIVERSITY, ZARIA

RESEARCH QUESTIONNAIRE: On the public awareness of heavy metal poisoning in Gusau, Zamfara State, Nigeria

INSTRUCTIONS: Kindly read and carefully answer the under listed questions correctly. The information given will be used solely for academic purposes. All information obtained will be treated in confidence. Thank you in anticipation for your cooperation and time spared as you willingly fill or tick the appropriate spaces or boxes provided.

Serial No …….

SECTION A: DEMOGRAPHIC INFORMATION

1. Age **:** (a) <15 [ ] (b) 16-30 [ ] (c) [ ] 30-45 [ ] (d) Above 45
2. Sex **:** Male [ ], Female [ ]
3. Level of Education **:** (a) No formal education [ ] (b) Quranic [ ] (c) Primary school [ ] (d) Secondary/ Commercial school [ ] (e) Tertiary/higher education [ ]
4. Occupation: (a) Farmer [ ] (b) Civil servant [ ] (c) Meat seller [ ] (d) Business [ ] (d) Student[ ] (e) Student [ ] (g) Miner (h) Housewife [ ]
5. Are you a meat seller or consumer? (a) Meat Seller [ ] (b) Consumer [ ] (c) Both
   If (a) answer section **B**, if (b) answer section

SECTION B: BUTCHERS/ MEAT SELLERS HANDLING OF MEAT

6. How long have you been butchering selling/meat (a) < 1yr[ ] (b) 2-10 yrs [ ] (c) above 10 yrs.
7. What type of meat do you butcher/sell? (a) Cattle [ ] (b) Sheep [ ] (c) Camel [ ] Others please specify----------
8. What are the sources of your fresh meat? (a) Zamfara [ ] (b) Other states [ ] please specify---------- (c) Outside Nigeria [ ]
9. What is the approximate number of people that patronize you per day? (a) < 20 [ ] (b)21-50 [ ] (c) 51-100 [ ] (d) > 100 [ ]
10. How do you transport your fresh meat from the source of buying to your retail outlet? (a) Car [ ] (b) Motor cycle[ ] (c) Bicycle [ ] (d) Wheel barrow [ ] (e) Foot [ ]
11. How do you package your fresh meat for transport? (a) Sacks [ ] (b) Buckets [ ] (b) Others please specify----------
12. Do you wash your meat before selling? (a) Yes [ ] (b) No [ ]
13. If yes how often do you wash the meat? (a) Frequently [ ] (b) Occasionally [ ] (c) Rarely [ ]
14. What is your source of water (a) Tap [ ] (b) Borehole [ ] (c) Well water (d) Others, please specify----------

SECTION C

MEAT SELLERS/ CONSUMERS KNOWLEDGE OF HEAVY METAL POISONING IN GUSAU.

15. Have you ever heard about heavy metal poisoning? (a) Yes [ ] (b) No [ ]
    If yes, answer question **18 - 33**
    If No, would you like to know?----------
16. Which metal did you hear was implicated in this poisoning? (a) Lead [ ]
    (b) Others please specify----------
17. How did you hear about it? (a) Television [ ] (b) Radio [ ] (c) News paper [ ] (d) Posters [ ] (e) Someone told me [ ]
18. Where did you hear that heavy metal poisoning occurred? (a) Gusau [ ] (b) Other

LGA's [ ]

20. Is heavy metal poisoning a problem? (a) Yes [ ] (b) No [ ]
21. Where could this problem be coming from? (a) Mining [ ] (b) Farming [ ]
    Others please specify ----------
22. Have you or any of your family members suffered from heavy metal poisoning recently? Whether nuclear or extended (a) Yes [ ] (b) No [ ]
23. If yes did you visit a hospital for treatment (a) Yes [ ] (b) No [ ]
24. Which members of the family suffered? (a) Children [ ] (b) Adults [ ]
25. What do think are possible sources of heavy metals to humans (a) Soil/dust [ ] (b) Water [ ] (c) Air [ ] (d) Food [ ] (e) Burning of tyre (f) All of the above
26. Who do you think are more susceptible to this problem? (a) Children [ ] (b) Adults [ ] (c) The aged [ ] (d) Every one [ ]

MEAT CONSUMPTION HABITS

27. What is your favorite meat? (a) Cow [ ] (b) Sheep [ ] (c) Camel meat [ ]
    Others please specify----------
28. In what form do you like to consume this meat? (a) Boiled [ ] (b) Roasted (c) Fried [ ]
29. How often do you consume this meat?
    (a) Frequently (daily to weekly) [ ] (b) Occasionally (weekly to monthly) [ ] (c) Rarely Once a month) [ ] (d) (e) Never [ ]
30. For how long have you been consuming this meat? (a) Since childhood [ ] (b) < 1yr [ ] (b) 2-10 yrs ago [ ] (c) above 10 yrs
31. Do you think this meat you consume could be contaminated with any heavy metal?
    (a) Yes [ ] (b) No [ ] (c) Maybe [ ]
32. What could be the possible routes of contamination? (a) Animals drank contaminated water [ ] (b) Animals consumed contaminated forage or feed [ ] (c) All of the above

Section C: RESPONDENTS RECOMMENDATION TO PROBLEM.

Would you support regulations of safer meat sales in Zamfara? (Please give reasons why)---------
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APPENDIX 11

Raw Data for Lead (mg/kg) in Beef, Mutton and Camel Meat

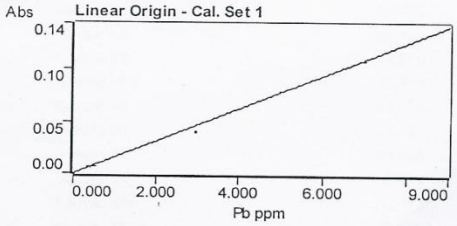
Lead final Results in mg/kg.

SpectrAA Report. 11:34 AM 6/27/2014 Page 1 of 6

Analyst	MUSRL/ABU Zaria
Date Started	4:27 PM 6/25/2014
Worksheet	Lead 0001 001 35
Comment	Miss Gladys Mikailu
Methods	Pb
Computer name	ABUZ-4F8B2314D4
Serial Number:	AA0904M046

No 1 – 100 is Mutton
101 – 200 is Camel Meat
201 – 300 is Beef

Method: Pb Water (Flame)



Sample ID	Conc ppm	SD	Mean Abs
Sample 1	53.831	0.0003	0.0067
Sample 2	58.835	0.0009	0.0073
Sample 3	63.136	0.0001	0.0079
Sample 4	30.477	0.0005	0.0038
Sample 5	51.194	0.0003	0.0064
Sample 6	33.499	0.0004	0.0042
Sample 7	66.652	0.0004	0.0062
Sample 8	36.308	0.0006	0.0045
Sample 9	63.799	0.0006	0.0040
Sample 10	48.880	0.0004	0.0061
Sample 11	28.735	0.0006	0.0036
Sample 12	77.781	0.0004	0.0097
Sample 13	151.556	0.0003	0.0189
Sample 14	25.872	0.0003	0.0032
Sample 15	26.437	0.0006	0.0033
Sample 16	26.624	0.0005	0.0033
Sample 17	29.792	0.0005	0.0037
Sample 18	21.431	0.0003	0.0027
Sample 19	25.724	0.0007	0.0032
Sample 20	24.449	0.0003	0.0030
Sample 21	29.455	0.0006	0.0037
Sample 22	26.277	0.0004	0.0033
Sample 23	37.965	0.0002	0.0047
Sample 24	35.950	0.0004	0.0045
Sample 25	36.568	0.0002	0.0045
Sample 26	35.004	0.0004	0.0044
Sample 27	34.022	0.0004	0.0042
Sample 28	40.220	0.0003	0.0050
Sample 29	38.878	0.0004	0.0048
Sample 30	36.148	0.0006	0.0045
Sample 31	36.449	0.0002	0.0045
Sample 32	31.569	0.0005	0.0039
Sample 33	32.250	0.0003	0.0040
Sample 34	29.721	0.0002	0.0037
Sample 35	48.011	0.0004	0.0060
Sample 36	28.136	0.0004	0.0035

Sample 37	28.668	0.0009	0.0036
Sample 38	47.540	0.0009	0.0059
Sample 39	29.833	0.0005	0.0037
Sample 40	43.751	0.0003	0.0054
Sample 41	35.653	0.0007	0.0044
Sample 42	34.710	0.0004	0.0043
Sample 43	31.229	0.0002	0.0039
Sample 44	30.087	0.0005	0.0037
Sample 45	25.823	0.0007	0.0032
Sample 46	22.585	0.0005	0.0028
Sample 47	38.918	0.0006	0.0048
Sample 48	43.716	0.0005	0.0054
Sample 49	43.725	0.0002	0.0054
Sample 50	33.399	0.0007	0.0042
Sample 51	33.466	0.0004	0.0042
Sample 52	52.810	0.0009	0.0066
Sample 53	38.648	0.0004	0.0048
Sample 54	39.868	0.0006	0.0050
Sample 55	58.235	0.0003	0.0072
Sample 56	53.050	0.0005	0.0066
Sample 57	61.812	0.0002	0.0077
Sample 58	122.737	0.0009	0.0076
Sample 59	101.847	0.0004	0.0063
Sample 60	89.005	0.0005	0.0056
Sample 61	126.010	0.0005	0.0078
Sample 62	118.595	0.0005	0.0074
Sample 63	124.158	0.0004	0.0077
Sample 64	146.266	0.0007	0.0091
Sample 65	121.667	0.0005	0.0076
Sample 66	117.067	0.0002	0.0073
Sample 67	110.555	0.0002	0.0069
Sample 68	139.993	0.0006	0.0087
Sample 69	113.402	0.0002	0.0071
Sample 70	224.338	0.0007	0.0140
Sample 71	80.622	0.0003	0.0050
Sample 72	99.300	0.0006	0.0062
Sample 73	93.822	0.0005	0.0058
Sample 74	90.908	0.0002	0.0057
Sample 75	84.603	0.0003	0.0053
Sample 76	119.068	0.0002	0.0074
Sample 77	100.399	0.0009	0.0062
Sample 78	98.462	0.0003	0.0061
Sample 79	140.142	0.0002	0.0087
Sample 80	113.566	0.0002	0.0071
Sample 81	97.466	0.0002	0.0061
Sample 82	78.387	0.0002	0.0049
Sample 83	112.006	0.0007	0.0070
Sample 84	120.853	0.0002	0.0075
Sample 85	83.790	0.0003	0.0052
Sample 86	97.800	0.0007	0.0061
Sample 87	147.142	0.0029	0.0092
Sample 88	106.691	0.0004	0.0093
Sample 89	145.525	0.0002	0.0091
Sample 90	130.179	0.0003	0.0081
Sample 91	122.209	0.0006	0.0076

Look for R on a H20, Hydr

Sample 92	109.451	0.0004	0.0068
Sample 93	101.046	0.0006	0.0063
Sample 94	142.477	0.0001	0.0089
Sample 95	92.789	0.0005	0.0058
Sample 96	182.938	0.0003	0.0114
Sample 97	63.362	0.0006	0.0039
Sample 98	67.937	0.0001	0.0042
Sample 99	84.772	0.0005	0.0053
Sample 100	90.187	0.0002	0.0056
✓ Sample 101	67.128	0.0003	0.0064
Sample 102	60.738	0.0003	0.0076
Sample 103	37.795	0.0005	0.0047
Sample 104	37.885	0.0007	0.0047
Sample 105	46.903	0.0002	0.0058
Sample 106	54.241	0.0002	0.0067
Sample 107	43.295	0.0005	0.0054
Sample 108	57.435	0.0002	0.0071
Sample 109	46.686	0.0004	0.0058
Sample 110	54.570	0.0002	0.0068
Sample 111	66.816	0.0002	0.0083
Sample 112	68.503	0.0002	0.0085
Sample 113	52.700	0.0005	0.0066
Sample 114	51.152	0.0005	0.0064
Sample 115	44.146	0.0007	0.0055
Sample 116	56.247	0.0002	0.0070
Sample 117	59.858	0.0002	0.0074
Sample 118	50.788	0.0002	0.0063
Sample 119	135.951 *	0.0008	0.0065
Sample 120	145.101	0.0005	0.0090
Sample 121	108.061	0.0004	0.0067
Sample 122	96.641	0.0006	0.0060
Sample 123	107.207	0.0003	0.0067
Sample 124	119.378	0.0003	0.0074
Sample 125	103.149	0.0002	0.0064
Sample 126	91.614	0.0002	0.0057
Sample 127	107.949	0.0004	0.0067
Sample 128	109.123	0.0003	0.0068
Sample 129	99.834	0.0007	0.0062
Sample 130	108.927	0.0006	0.0067
Sample 131	104.361	0.0002	0.0065
Sample 132	93.921	0.0009	0.0058
Sample 133	101.998	0.0007	0.0063
Sample 134	118.948	0.0005	0.0074
Sample 135	87.995	0.0001	0.0055
Sample 136	108.920	0.0002	0.0068
Sample 137	109.421	0.0004	0.0068
Sample 138	105.818	0.0005	0.0066
Sample 139	105.976	0.0003	0.0066
Sample 140	92.667	0.0002	0.0058
Sample 141	104.580	0.0003	0.0065
Sample 142	93.186	0.0002	0.0059
Sample 143	106.792	0.0003	0.0066
Sample 144	99.064	0.0005	0.0062
Sample 145	93.613	0.0004	0.0058
Sample 146	72.805	0.0007	0.0045

Sample 147	95.145	0.0004	0.0059
Sample 148	185.762	0.0006	0.0110
Sample 149	106.004	0.0004	0.0065
Sample 150	108.520	0.0007	0.0068
Sample 151	111.367	0.0002	0.0069
Sample 152	99.302	0.0003	0.0060
Sample 153	106.506	0.0005	0.0066
Sample 154	104.274	0.0004	0.0065
Sample 155	111.044	0.0002	0.0069
Sample 156	103.153	0.0005	0.0064
Sample 157	175.850	0.0004	0.0109
Sample 158	95.169	0.0004	0.0059
Sample 159	99.524	0.0001	0.0062
Sample 160	105.261	0.0004	0.0065
Sample 161	94.288	0.0004	0.0059
Sample 162	95.929	0.0007	0.0060
Sample 163	98.266	0.0008	0.0061
Sample 164	73.370	0.0005	0.0046
Sample 165	72.492	0.0004	0.0045
Sample 166	81.327	0.0004	0.0051
Sample 167	93.842	0.0009	0.0058
Sample 168	100.195	0.0004	0.0062
Sample 169	106.519	0.0004	0.0066
Sample 170	110.996	0.0004	0.0069
Sample 171	97.299	0.0005	0.0061
Sample 172	106.653	0.0005	0.0066
Sample 173	111.139	0.0002	0.0069
Sample 174	112.649	0.0001	0.0070
Sample 175	120.256	0.0006	0.0075
Sample 176	113.862	0.0003	0.0071
Sample 177	118.062	0.0003	0.0073
Sample 178	118.452	0.0007	0.0074
Sample 179	97.743	0.0004	0.0061
Sample 180	115.542	0.0003	0.0072
Sample 181	114.618	0.0007	0.0071
Sample 182	123.248	0.0002	0.0077
Sample 183	116.633	0.0005	0.0073
Sample 184	114.091	0.0005	0.0071
Sample 185	139.294	0.0005	0.0087
Sample 186	188.365	0.0002	0.0117
Sample 187	102.882	0.0010	0.0064
Sample 188	115.531	0.0003	0.0072
Sample 189	100.903	0.0006	0.0063
Sample 190	110.451	0.0004	0.0069
Sample 191	96.719	0.0004	0.0060
Sample 192	114.030	0.0003	0.0071
Sample 193	96.896	0.0006	0.0060
Sample 194	129.729	0.0002	0.0081
Sample 195	126.051	0.0004	0.0078
Sample 196	102.170	0.0006	0.0064
Sample 197	99.175	0.0004	0.0062
Sample 198	94.002	0.0007	0.0058
Sample 199	106.226	0.0005	0.0066
Sample 200	115.215	0.0003	0.0072
Sample 201	64.307	0.0007	0.0040

Sample 202	65.794	0.0001	0.0060
Sample 203	102.632	0.0006	0.0126
Sample 204	46.097	0.0004	0.0057
Sample 205	52.334	0.0003	0.0065
Sample 206	118.956	0.0004	0.0074
Sample 207	99.681	0.0005	0.0074
Sample 208	118.780	0.0005	0.0074
Sample 209	80.786	0.0003	0.0050
Sample 210	60.593	0.0007	0.0063
Sample 211	60.675	0.0004	0.0075
Sample 212	160.907	0.0002	0.0100
Sample 213	104.252	0.0005	0.0065
Sample 214	67.218	0.0003	0.0084
Sample 215	48.626	0.0002	0.0061
Sample 216	77.380	0.0001	0.0038
Sample 217	41.217	0.0001	0.0051
Sample 218	60.124	0.0004	0.0062
Sample 219	67.635	0.0001	0.0084
Sample 220	63.963	0.0001	0.0080
Sample 221	62.967	0.0004	0.0078
Sample 222	61.778	0.0002	0.0077
Sample 223	66.559	0.0006	0.0083
Sample 224	59.200	0.0002	0.0074
Sample 225	100.844	0.0004	0.0126
Sample 226	49.594	0.0006	0.0062
Sample 227	102.876	0.0001	0.0128
Sample 228	73.243	0.0003	0.0091
Sample 229	56.910	0.0001	0.0071
Sample 230	97.579	0.0006	0.0122
Sample 231	72.188	0.0004	0.0090
Sample 232	63.909	0.0004	0.0080
Sample 233	90.371	0.0001	0.0112
Sample 234	46.588	0.0009	0.0060
Sample 235	115.926	0.0003	0.0087
Sample 236	52.416	0.0002	0.0065
Sample 237	57.059	0.0002	0.0071
Sample 238	108.154	0.0008	0.0081
Sample 239	64.371	0.0004	0.0080
Sample 240	66.393	0.0004	0.0083
Sample 241	51.717	0.0002	0.0064
Sample 242	107.463	0.0002	0.0060
Sample 243	55.536	0.0006	0.0069
Sample 244	95.553	0.0009	0.0119
Sample 245	57.291	0.0002	0.0071
Sample 246	53.365	0.0010	0.0066
Sample 247	46.892	0.0003	0.0058
Sample 248	51.921	0.0003	0.0061
Sample 249	99.981	0.0006	0.0062
Sample 250	110.961	0.0004	0.0069
Sample 251	92.749	0.0001	0.0058
Sample 252	94.868	0.0004	0.0059
Sample 253	100.261	0.0002	0.0062
Sample 254	112.016	0.0001	0.0070
Sample 255	101.957	0.0001	0.0063
Sample 256	100.156	0.0005	0.0062

Sample 257	130.182	0.0003	0.0081
Sample 258	112.206	0.0002	0.0070
Sample 259	129.272	0.0006	0.0080
Sample 260	104.577	0.0003	0.0065
Sample 261	105.457	0.0005	0.0066
Sample 262	111.541	0.0006	0.0069
Sample 263	103.948	0.0002	0.0065
Sample 264	108.453	0.0001	0.0067
Sample 265	121.462	0.0003	0.0076
Sample 266	105.691	0.0002	0.0066
Sample 267	114.345	0.0005	0.0071
Sample 268	103.143	0.0005	0.0064
Sample 269	92.009	0.0005	0.0057
Sample 270	116.175	0.0004	0.0072
Sample 271	119.741	0.0004	0.0074
Sample 272	106.513	0.0001	0.0066
Sample 273	108.169	0.0004	0.0067
Sample 274	121.086	0.0005	0.0075
Sample 275	121.286	0.0009	0.0075
Sample 276	153.213	0.0005	0.0095
Sample 277	124.201	0.0003	0.0077
Sample 278	110.275	0.0003	0.0069
Sample 279	98.099	0.0003	0.0061
Sample 280	90.258	0.0002	0.0056
Sample 281	111.689	0.0004	0.0069
Sample 282	123.073	0.0002	0.0077
Sample 283	103.226	0.0007	0.0064
Sample 284	97.994	0.0003	0.0061
Sample 285	146.055	0.0004	0.0091
Sample 286	105.018	0.0005	0.0065
Sample 287	162.758	0.0003	0.0101
Sample 288	104.758	0.0004	0.0065
Sample 289	94.559	0.0004	0.0059
Sample 290	185.307	0.0006	0.0115
Sample 291	100.863	0.0001	0.0063
Sample 292	119.882	0.0010	0.0075
Sample 293	127.086	0.0003	0.0079
Sample 294	104.828	0.0005	0.0065
Sample 295	122.466	0.0002	0.0076
Sample 296	102.990	0.0006	0.0064
Sample 297	102.622	0.0005	0.0064
Sample 298	98.501	0.0006	0.0061
Sample 299	99.893	0.0010	0.0062
Sample 300	98.113	0.0001	0.0061

APPENDIX 11I

Raw Data for Cadmium (mg/kg) in Beef, Mutton and Camel Meat

Cadmium Final Results in Mg/kg.

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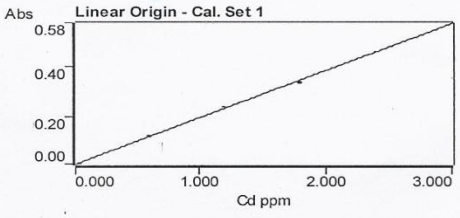
Analyst	MUSRL/ABU Zaria
Date Started	7:15 PM 6/25/2014
Worksheet	Cadmium 0001 91
Comment	Miss Gladys Mikailu
Methods	Cd
Computer name	ABUZ-4F8B2314D4
Serial Number:	AA0904M046

NO 1 – 100 is Mutton
101 – 200 is Camel Meat
201 – 300 is Beef

Method: Cd Water (Flame)



Sample ID	Conc ppm	SD	Mean Abs
Sample 1	0.750	0.0004	0.0011
Sample 2	0.648	0.0004	0.0010
Sample 3	0.629	0.0002	0.0010
Sample 4	0.232	0.0002	0.0004
Sample 5	0.259	0.0003	0.0004
Sample 6	0.045	0.0003	0.0001
Sample 7	0.000	0.0004	-0.0004
Sample 8	0.102	0.0002	0.0002
Sample 9	1.373	0.0002	0.0011
Sample 10	1.016	0.0001	0.0016
Sample 11	0.601	0.0002	0.0009
Sample 12	0.525	0.0003	0.0008
Sample 13	0.260	0.0004	0.0004
Sample 14	0.173	0.0002	0.0003
Sample 15	0.340	0.0003	0.0005
Sample 16	0.173	0.0002	0.0003
Sample 17	0.547	0.0002	0.0008
Sample 18	0.249	0.0004	0.0004
Sample 19	0.521	0.0002	0.0008
Sample 20	1.046	0.0004	0.0016
Sample 21	0.652	0.0003	0.0010
Sample 22	0.888	0.0002	0.0014
Sample 23	0.827	0.0003	0.0013
Sample 24	0.881	0.0003	0.0014
Sample 25	0.806	0.0003	0.0012
Sample 26	0.816	0.0003	0.0013
Sample 27	1.108	0.0005	0.0017
Sample 28	1.206	0.0002	0.0018
Sample 29	1.390	0.0003	0.0021
Sample 30	1.449	0.0002	0.0022
Sample 31	1.418	0.0001	0.0022
Sample 32	1.364	0.0006	0.0021
Sample 33	1.572	0.0003	0.0024
Sample 34	1.099	0.0002	0.0017
Sample 35	1.213	0.0003	0.0019
Sample 36	1.407	0.0005	0.0022

Sample 37	1.488	0.0002	0.0023
Sample 38	1.453	0.0002	0.0022
Sample 39	1.216	0.0003	0.0019
Sample 40	1.372	0.0004	0.0021
Sample 41	1.638	0.0002	0.0025
Sample 42	1.338	0.0002	0.0021
Sample 43	1.487	0.0005	0.0023
Sample 44	1.454	0.0002	0.0022
Sample 45	1.585	0.0006	0.0024
Sample 46	1.454	0.0003	0.0022
Sample 47	1.358	0.0003	0.0021
Sample 48	1.385	0.0005	0.0021
Sample 49	1.504	0.0002	0.0023
Sample 50	1.028	0.0001	0.0016
Sample 51	1.148	0.0003	0.0018
Sample 52	5.682	0.0001	0.0087
Sample 53	1.780	0.0002	0.0027
Sample 54	1.863	0.0004	0.0029
Sample 55	7.051	0.0006	0.0108
Sample 56	5.011	0.0003	0.0077
Sample 57	1.359	0.0000	0.0021
Sample 58	7.265	0.0002	0.0056
Sample 59	6.964	0.0004	0.0053
Sample 60	2.812	0.0003	0.0022
Sample 61	11.772	0.0003	0.0090
Sample 62	3.069	0.0002	0.0024
Sample 63	11.066	0.0002	0.0085
Sample 64	11.838	0.0001	0.0091
Sample 65	8.848	0.0007	0.0068
Sample 66	3.380	0.0003	0.0026
Sample 67	4.381	0.0005	0.0034
Sample 68	20.987	0.0002	0.0161
Sample 69	12.402	0.0000	0.0095
Sample 70	6.281	0.0006	0.0048
Sample 71	7.100	0.0001	0.0054
Sample 72	12.247	0.0002	0.0094
Sample 73	7.425	0.0002	0.0057
Sample 74	6.164	0.0006	0.0047
Sample 75	7.829	0.0004	0.0060
Sample 76	9.664	0.0003	0.0074
Sample 77	9.639	0.0007	0.0074
Sample 78	16.730	0.0003	0.0128
Sample 79	15.114	0.0004	0.0116
Sample 80	16.049	0.0003	0.0123
Sample 81	16.365	0.0002	0.0125
Sample 82	8.703	0.0001	0.0067
Sample 83	15.423	0.0002	0.0118
Sample 84	15.513	0.0005	0.0119
Sample 85	9.659	0.0005	0.0074
Sample 86	9.942	0.0004	0.0076
Sample 87	16.902	0.0003	0.0130
Sample 88	13.644	0.0005	0.0105
Sample 89	21.586	0.0001	0.0165
Sample 90	19.450	0.0001	0.0149
Sample 91	18.536	0.0000	0.0142

Sample 92	15.423	0.0001	0.0118
Sample 93	15.980	0.0007	0.0122
Sample 94	18.083	0.0005	0.0139
Sample 95	16.392	0.0001	0.0126
Sample 96	17.064	0.0003	0.0131
Sample 97	11.920	0.0007	0.0091
Sample 98	11.730	0.0004	0.0090
Sample 99	12.432	0.0002	0.0095
Sample 100	12.716	0.0001	0.0097
Sample 101	6.023	0.0001	0.0092
Sample 102	6.157	0.0003	0.0094
Sample 103	6.604	0.0003	0.0101
Sample 104	6.740	0.0006	0.0103
Sample 105	6.520	0.0003	0.0100
Sample 106	6.612	0.0006	0.0101
Sample 107	6.507	0.0001	0.0100
Sample 108	6.578	0.0004	0.0101
Sample 109	5.958	0.0005	0.0091
Sample 110	7.299	0.0004	0.0112
Sample 111	7.160	0.0002	0.0110
Sample 112	7.462	0.0003	0.0114
Sample 113	7.471	0.0002	0.0114
Sample 114	7.834	0.0002	0.0120
Sample 115	8.155	0.0004	0.0125
Sample 116	8.245	0.0002	0.0126
Sample 117	7.852	0.0002	0.0120
Sample 118	8.210	0.0003	0.0126
Sample 119	16.531	0.0002	0.0127
Sample 120	17.540	0.0000	0.0134
Sample 121	17.164	0.0003	0.0132
Sample 122	17.216	0.0004	0.0132
Sample 123	17.378	0.0007	0.0133
Sample 124	18.211	0.0002	0.0140
Sample 125	17.795	0.0003	0.0136
Sample 126	18.096	0.0004	0.0139
Sample 127	18.587	0.0005	0.0142
Sample 128	18.157	0.0001	0.0139
Sample 129	17.613	0.0003	0.0135
Sample 130	18.514	0.0004	0.0142
Sample 131	18.185	0.0005	0.0139
Sample 132	18.248	0.0007	0.0140
Sample 133	18.595	0.0005	0.0142
Sample 134	18.669	0.0001	0.0143
Sample 135	18.193	0.0004	0.0139
Sample 136	19.092	0.0004	0.0146
Sample 137	19.058	0.0002	0.0146
Sample 138	19.117	0.0006	0.0146
Sample 139	19.249	0.0002	0.0148
Sample 140	19.247	0.0002	0.0147
Sample 141	18.498	0.0002	0.0142
Sample 142	18.165	0.0002	0.0139
Sample 143	18.893	0.0004	0.0145
Sample 144	19.522	0.0003	0.0150
Sample 145	19.845	0.0001	0.0152
Sample 146	20.235	0.0004	0.0155

Sample 147	19.574	0.0006	0.0150
Sample 148	22.993	0.0002	0.0176
Sample 149	19.752	0.0004	0.0152
Sample 150	20.372	0.0002	0.0156
Sample 151	20.533	0.0005	0.0157
Sample 152	20.156	0.0005	0.0154
Sample 153	21.161	0.0003	0.0162
Sample 154	22.142	0.0002	0.0170
Sample 155	21.409	0.0004	0.0164
Sample 156	19.747	0.0002	0.0151
Sample 157	19.589	0.0006	0.0150
Sample 158	20.032	0.0002	0.0154
Sample 159	20.915	0.0003	0.0160
Sample 160	20.716	0.0005	0.0159
Sample 161	20.185	0.0003	0.0155
Sample 162	20.899	0.0002	0.0160
Sample 163	21.627	0.0002	0.0166
Sample 164	19.898	0.0005	0.0152
Sample 165	19.940	0.0005	0.0153
Sample 166	21.446	0.0002	0.0164
Sample 167	19.790	0.0003	0.0152
Sample 168	22.263	0.0001	0.0171
Sample 169	19.893	0.0005	0.0152
Sample 170	20.374	0.0002	0.0156
Sample 171	22.148	0.0003	0.0170
Sample 172	21.272	0.0005	0.0163
Sample 173	21.491	0.0002	0.0165
Sample 174	21.755	0.0001	0.0167
Sample 175	21.811	0.0003	0.0167
Sample 176	20.950	0.0003	0.0161
Sample 177	20.919	0.0002	0.0160
Sample 178	23.458	0.0002	0.0180
Sample 179	20.464	0.0003	0.0157
Sample 180	20.428	0.0005	0.0157
Sample 181	25.108	0.0001	0.0192
Sample 182	25.157	0.0004	0.0193
Sample 183	24.221	0.0003	0.0186
Sample 184	23.912	0.0002	0.0183
Sample 185	31.599	0.0001	0.0242
Sample 186	20.872	0.0002	0.0160
Sample 187	21.686	0.0003	0.0166
Sample 188	24.382	0.0003	0.0187
Sample 189	22.416	0.0001	0.0172
Sample 190	22.499	0.0005	0.0172
Sample 191	21.781	0.0004	0.0167
Sample 192	25.585	0.0002	0.0196
Sample 193	22.259	0.0004	0.0171
Sample 194	26.476	0.0003	0.0203
Sample 195	25.715	0.0002	0.0197
Sample 196	23.204	0.0001	0.0178
Sample 197	23.049	0.0004	0.0177
Sample 198	22.256	0.0001	0.0171
Sample 199	21.943	0.0002	0.0168
Sample 200	21.866	0.0000	0.0168
Sample 201	11.319	0.0007	0.0173

Sample 202	10.959	0.0004	0.0168
Sample 203	10.980	0.0005	0.0168
Sample 204	11.098	0.0003	0.0170
Sample 205	10.817	0.0007	0.0166
Sample 206	21.063	0.0005	0.0161
Sample 207	10.720	0.0001	0.0164
Sample 208	28.855	0.0004	0.0221
Sample 209	22.489	0.0004	0.0172
Sample 210	10.912	0.0000	0.0167
Sample 211	10.895	0.0004	0.0167
Sample 212	21.420	0.0002	0.0164
Sample 213	22.540	0.0004	0.0173
Sample 214	11.220	0.0002	0.0172
Sample 215	11.276	0.0002	0.0173
Sample 216	11.459	0.0001	0.0176
Sample 217	11.307	0.0003	0.0173
Sample 218	11.683	0.0003	0.0179
Sample 219	11.225	0.0003	0.0172
Sample 220	11.557	0.0002	0.0177
Sample 221	11.888	0.0001	0.0182
Sample 222	11.680	0.0002	0.0179
Sample 223	11.750	0.0002	0.0180
Sample 224	11.906	0.0001	0.0182
Sample 225	11.599	0.0003	0.0178
Sample 226	11.774	0.0003	0.0180
Sample 227	11.980	0.0007	0.0184
Sample 228	11.994	0.0004	0.0184
Sample 229	12.553	0.0004	0.0192
Sample 230	12.414	0.0003	0.0190
Sample 231	12.480	0.0004	0.0191
Sample 232	12.130	0.0005	0.0186
Sample 233	12.409	0.0003	0.0190
Sample 234	12.835	0.0000	0.0197
Sample 235	21.000	0.0005	0.0193
Sample 236	12.597	0.0003	0.0193
Sample 237	12.749	0.0004	0.0195
Sample 238	21.868	0.0000	0.0201
Sample 239	12.856	0.0002	0.0197
Sample 240	12.694	0.0005	0.0195
Sample 241	12.583	0.0004	0.0193
Sample 242	29.309	0.0002	0.0202
Sample 243	13.062	0.0003	0.0200
Sample 244	12.769	0.0003	0.0196
Sample 245	13.082	0.0003	0.0200
Sample 246	13.010	0.0003	0.0199
Sample 247	13.243	0.0005	0.0203
Sample 248	22.127	0.0004	0.0203
Sample 249	27.650	0.0006	0.0212
Sample 250	28.932	0.0004	0.0222
Sample 251	26.077	0.0004	0.0200
Sample 252	27.292	0.0003	0.0209
Sample 253	27.007	0.0005	0.0207
Sample 254	25.917	0.0006	0.0199
Sample 255	29.561	0.0002	0.0227
Sample 256	25.198	0.0001	0.0193

Sample 257	25.511	0.0004	0.0195
Sample 258	25.079	0.0005	0.0192
Sample 259	27.344	0.0004	0.0210
Sample 260	29.480	0.0002	0.0226
Sample 261	27.154	0.0002	0.0208
Sample 262	30.427	0.0005	0.0233
Sample 263	30.915	0.0004	0.0237
Sample 264	30.478	0.0006	0.0234
Sample 265	27.244	0.0002	0.0209
Sample 266	26.792	0.0001	0.0205
Sample 267	29.156	0.0004	0.0223
Sample 268	30.299	0.0003	0.0232
Sample 269	30.063	0.0001	0.0230
Sample 270	27.263	0.0002	0.0209
Sample 271	26.742	0.0001	0.0205
Sample 272	26.662	0.0001	0.0204
Sample 273	26.585	0.0005	0.0204
Sample 274	28.089	0.0003	0.0215
Sample 275	31.202	0.0003	0.0239
Sample 276	26.183	0.0003	0.0201
Sample 277	25.869	0.0004	0.0198
Sample 278	26.996	0.0009	0.0207
Sample 279	26.784	0.0005	0.0205
Sample 280	27.553	0.0004	0.0211
Sample 281	27.657	0.0003	0.0212
Sample 282	30.519	0.0003	0.0234
Sample 283	28.769	0.0004	0.0220
Sample 284	25.805	0.0003	0.0198
Sample 285	26.326	0.0003	0.0202
Sample 286	30.449	0.0004	0.0233
Sample 287	29.138	0.0003	0.0223
Sample 288	27.197	0.0005	0.0208
Sample 289	27.359	0.0003	0.0210
Sample 290	35.126	0.0006	0.0269
Sample 291	26.908	0.0003	0.0206
Sample 292	28.631	0.0003	0.0219
Sample 293	30.053	0.0004	0.0230
Sample 294	27.523	0.0002	0.0211
Sample 295	31.977	0.0006	0.0245
Sample 296	30.422	0.0004	0.0233
Sample 297	31.736	0.0002	0.0243
Sample 298	27.885	0.0007	0.0214
Sample 299	27.990	0.0002	0.0214
Sample 300	27.571	0.0003	0.0211