CADMIUM AND ZINC LEVELS IN COW OFFALS SOLD WITHIN BENIN CITY METROPOLIS

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CERTIFICATION

This is to certify that this project work and research was carried out by **Karenhappuch Ikpemosi Dako** with the matriculation number **PSC2105215** of the Chemistry Department, Faculty of Physical Sciences, University of Benin**.**

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Prof. E.E.I. Irabor (Head of Department)	**Date**

DEDICATION

I dedicate this project to God Almighty, for His unending grace, strength and wisdom throughout this journey.

And to my beloved grandmother, Grandma Mispah Poku, whose love, prayers and legacy continue to inspire me. I hope I’ve made you proud.

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To my amazing parents, thank you for your unwavering love, support, and sacrifices. I’m deeply grateful.

To my siblings, thank you for your encouragement and for cheering me on every step of the way.

To my friends, thank you for being a constant source of strength, laughter, and motivation during this journey.

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TABLE OF CONTENT

CHAPTER ONE

CHAPTER 2

CHAPTER THREE

ABSTRACT

This study investigated the levels of cadmium (Cd) and zinc (Zn) in cow offal (shaki, liver and kidney) consumed within Benin City to assess potential human health risks associated with its exposure. Samples of liver, kidney, and intestine were collected from three different abattoirs (University of Benin abattoir, University of Benin Teaching Hospital (UBTH) abattoir and Ekosodin abattoir) and analyzed using an Atomic Absorption Spectrophotometer (AAS) to determine the heavy metal concentrations. Results showed cadmium levels ranging below detectable limits to 1.00 mg/kg was obtained for the duration of the sampling campaign with the highest concentration obtained in Ekosodin market and University of Benin abattoir. Also noteworthy is that cadmium was detected in 25% of all the samples collected. The concentration obtained in this study was found to exceed the Codex Alimentarius limits of 0.5 mg/kg in liver and 1.0 mg/kg in kidney. Zinc concentrations, though essential, were also found in higher than recommended amounts, suggesting contamination from feed or environmental sources. A zinc concentration range of 47 to 197 mg/kg was obtained with the highest concentration obtained in kidney sample from Ekosodin market with a concentration of 197mg/kg while the lowest concentration of 47 mg/kg was obtained in intestine sample from University of Benin Teaching Hospital abattoir. The elevated metal content reported poses potential health risks, especially for vulnerable groups such as pregnant women, children, and the elderly. The findings highlight the need for continuous monitoring of slaughterhouse practices, feed sources, and environmental pollution. Increased public awareness and enforcement of food safety regulations are essential to minimize exposure and protect public health.

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS AND SYMBOLS

AAS – Atomic Absorption Spectrometer

CODEX – Codex Alimentarius Commission

JECFA – Joint FAO/WHO Expert Committee on Food Additives

FAO – Food and Agriculture Organization

WHO – World Health Organization

Pb - Lead

Zn - Zinc

Cd – Cadmium

Cr - Chromium

Hg - Mercury

Ni – Nickel

Co - Cobalt

Cu – Copper

Fe - Iron

Mn - Manganese

Mo - Molybdenum

Se - Selenium

HNO_3 - Nitric Acid

$HClO_4$ - Perchloric Acid

H_2O - Water (Distilled Water)

UNIBEN – University of Benin

UBTH – University of Benin Teaching Hospital

CHAPTER ONE

INTRODUCTION AND LITERATURE REVIEW

1.1 INTRODUCTION

1.1.1 BACKGROUND OF STUDY

Environmental Pollution is defined as “the presence of a substance in the environment that, because of its chemical composition or quantity, prevents the functioning of natural processes and produces undesirable environmental or health effects.” (United Nations Environment Programme, UNEP, 2016). It results from both natural processes and human activities such as urbanization, industrialization, etc.- with the latter being the dominant contributor. This pollution affects various media: atmosphere (air), lithosphere (soil), hydrosphere (water) and the biosphere (living things) leading to several consequences such as environmental degradation, depletion of the ozone layer, reduction in the human life expectancy rate, loss of biodiversity, to name a few.

Pollution sources are generally classified into two main categories: point sources and non-point sources. Point sources refer to identifiable, localized origins of pollutants—such as industrial facilities, power plants, refineries, and wastewater treatment plants. In contrast, nonpoint sources are diffuse and spread over large areas, often difficult to trace to a single origin. Examples include runoff from urban landscapes or agricultural fields, as well as mobile sources like vehicles, which contribute pollutants across wide geographic areas rather than at a fixed location (Green Chemistry, 2018). Industries such as food processing, leather tanning, and textile manufacturing are known to be major contributors to water pollution, primarily due to the discharge of untreated liquid waste directly into rivers. These industrial effluents often originate from processing plants and are released without sufficient treatment.

In many cases, rivers are simultaneously exposed to pollutants from multiple industrial sources, intensifying their environmental impact (Ademe and Alemayehu, 2014; Wosnie and Wondie, 2014).

Pollution is commonly divided into various types depending on the characteristics of the contaminants and the specific part of the environment they impact. Chemically, pollutants are typically grouped into organic and inorganic categories, based on their molecular structure and how they interact with the environment" (Singh and Sharma, 2020; Cunningham and Cunningham, 2017).

Organic pollutants are carbon-based chemical substances that often include hydrogen, along with other elements such as oxygen, nitrogen, or halogens. These compounds may originate from natural sources or be synthetically produced, and they enter the environment primarily through anthropogenic activities. Their classification is typically based on structural characteristics, origin, and behavior in the environment (Jones and de Voogt, 1999). Organic pollutants comprise a wide array of chemical substances, many of which pose significant risks to environmental and human health. Among the most concerning are Persistent Organic Pollutants (POPs)—toxic compounds that resist environmental degradation, bioaccumulate in living organisms, and can be transported over long distances through air and water systems (Jones and de Voogt, 1999). Volatile Organic Compounds (VOCs) represent another major group; their high vapor pressure enables them to readily volatilize into the atmosphere, contributing to air pollution and causing adverse health effects such as respiratory irritation (U.S. EPA, 2020). Polycyclic Aromatic Hydrocarbons (PAHs), typically produced through the incomplete combustion of organic matter, are notable for their carcinogenic and mutagenic potential (Maliszewska-Kordybach, 1999). Additionally, Pharmaceuticals and

Personal Care Products (PPCPs), an emerging class of contaminants, are increasingly detected in aquatic systems via wastewater effluents and have been shown to disrupt ecological balance even at low concentrations (Daughton and Ternes, 1999). As a result of their differing origins, chemical properties, and environmental consequences, these pollutants require a range of management and remediation approaches.

Organic pollutants originate from a variety of human activities. Some of the sources of organic pollution range from industrial processes such as chemical production, petroleum refining, and textile manufacturing which discharge significant quantities of organic compounds into the environment to agriculture which surmises the use of pesticides and herbicides and can result in these chemicals seeping into surrounding soil and water bodies to household activities, including the use of cleaning products, poor waste management, and the disposal of personal care items, which also contribute to organic pollution and additionally to transportation, particularly from vehicle exhaust, emits pollutants like volatile organic compounds (VOCs) and polycyclic aromatic hydrocarbons (PAHs) into the atmosphere.

Inorganic pollutants are chemical substances that typically lack carbon-hydrogen bonds and include a wide range of materials such as heavy metals, salts, acids, and other mineral-derived compounds. Although many of these substances are naturally present in the environment, anthropogenic activities—such as industrial emissions, mining, and agriculture—have significantly elevated their levels, leading to environmental and health concerns (Alloway, 2013). Inorganic pollutants encompass a diverse group of chemical substances that originate from both natural processes and human activities, often contributing significantly to environmental degradation. Among the most concerning are heavy metals, including lead (Pb), zinc (Zn), copper (Cu), cadmium (Cd), and chromium (Cr). These elements are commonly introduced into the environment through industrial activities, mining operations, and the careless disposal of hazardous waste. Due to their toxicity and persistence, heavy metals can contaminate soil and water, posing serious risks to ecosystems and human health (Tchounwou et al., 2012). Another major category involves acids and bases, primarily arising from the combustion of fossil fuels. Gases like sulfur dioxide (SO_2) and nitrogen oxides (NO_x) are emitted into the atmosphere, where they react with water vapor to form acid rain. This phenomenon leads to soil acidification, aquatic ecosystem damage, and the deterioration of buildings and infrastructure (Driscoll *et al*., 2001). Salts and nutrients, such as excess nitrates and phosphates, are typically introduced through agricultural runoff and untreated sewage. When these compounds enter aquatic environments in large quantities, they can trigger eutrophication—a process that stimulates excessive algal growth, depletes oxygen levels, and ultimately harms aquatic life (Smith *et al*., 1999). In addition, various other inorganic compounds, including fluoride, chlorides, and cyanides, contribute to pollution in specific contexts. These substances may originate from industrial effluents, water treatment processes, or chemical manufacturing and can pose localized but severe threats to both the environment and public health (Duruibe, *et al.*, 2007). The study of the various types of inorganic pollutants is crucial for developing effective environmental protection strategies and alleviating their harmful impacts.

Heavy metals are a group of naturally occurring metallic elements that have a high atomic weight and a density at least five times greater than that of water ($5 g/cm^3$). They are characterized by their toxicity at low concentrations, persistence in the environment, and tendency to bioaccumulate in living organisms (Tchounwou *et al*., 2012). Metals such as cobalt (Co), copper (Cu), chromium (Cr), iron (Fe), manganese (Mn), molybdenum (Mo), nickel (Ni), selenium (Se), and zinc (Zn) are considered essential nutrients, as they are required in trace amounts for various biochemical and physiological functions in living organisms. However, when present in excess, these metals can become toxic, leading to cellular and tissue damage (Tchounwou, *et al.*, 2012). Heavy metals can get into the body via various routes: inhalation, dermal contact or ingestion.

1.1.2 STATEMENT OF PROBLEM

In a study by the International Livestock Centre for Africa (ILCA) (Akinwumi *et al.*, 1991) it was reported that among pastoralist communities in Nigeria, approximately 20% were fully nomadic**,** 50% semi-nomadic**,** and 30% fully settled**.** In nomadic pastoralism, cattles move from place-to-place consuming grasses, water and feed that may be contaminated by heavy metals as a result of various human activities. These heavy metals are deposited in certain offal parts such as the kidney and liver upon digestion because they are not biodegradable and can bioaccumulate in the food chain leading to significant health risk for human on consumption. Studies have shown that heavy metals in animal offal can pose serious carcinogenic risks**,** particularly to vulnerable populations such as children and adults**,** due to the bioaccumulation of toxic elements like lead, cadmium, and chromium. These findings emphasize the urgent need for regular monitoring and regulation of food products containing offal to protect public health (Ogbomida *et al*., 2018).

Offal—organ meats including the liver, kidney, and intestines—is widely consumed in many communities due to its affordability and nutritional value and though a number of studies have assessed heavy metal contamination in meat, very few have focused on offal, despite its higher tendency to accumulate these substances. The absence of comprehensive regulatory guidelines and systematic monitoring for heavy metals in animal offal poses a significant public health challenge. This gap is particularly concerning because certain populations—such as children, pregnant women, and immunocompromised individuals—are more vulnerable to the toxic effects of heavy metal exposure. These contaminants can accumulate in edible organs, and without effective surveillance and regulation, the risk of adverse health outcomes increases for these sensitive groups (World Health Organization [WHO], 2010; United States Environmental Protection Agency [EPA], 2012).

In many developing regions, regulatory monitoring of heavy metals in food products, especially offal, is often inadequate or inconsistent. This lack of routine quality checks increases the risk of contaminated offal reaching consumers, who may be unaware of the dangers it poses. In addition, there is a gap in public knowledge regarding the health implications associated with the consumption of contaminated animal organs which further compounds the problem.

For these reasons, there is an urgent need for a systematic assessment of heavy metal concentrations in cow offal and a thorough evaluation of the potential health risks posed to consumers. The absence of sufficient data limits the ability to develop effective policies, enforce food safety regulations, and raise public awareness about safe consumption habits. Addressing this issue is essential for protecting public health, guiding policy formulation, and informing targeted interventions aimed at minimizing heavy metal exposure through the food chain. This study thus seeks to fill existing knowledge gaps by quantifying selected heavy metals in cow offal and assessing the associated health risks from their consumption. The results are expected to provide valuable insights for public health authorities, enhance consumer awareness, and support evidence-based measures—such as strengthened environmental regulations and more rigorous food safety standards—to effectively reduce the risks linked to dietary heavy metal exposure.

1.1.3 JUSTIFICATION OF STUDY

The justification of this study arises from the increasing concern over environmental pollution and its implications for food safety particularly regarding the accumulation of heavy metals in livestock products such as the offal of cattle. Offal is a common dietary component in many communities because of its low cost and nutritional benefits; however, there is limited research on the presence of these contaminants with their potential health risks. Heavy metals such as lead, cadmium, and chromium are toxic even at low concentrations and prolonged exposure can lead to serious health issues including organ damage**,** neurological disorders**,** and an increased risk of cancer (Khoshakhlagh, A.H. *et al.*, 2024; Nieder, R. and Benbi, D.K**.**, 2022).

This study provides essential empirical data on the concentration of heavy metals in the offal of cattle and evaluates the associated health risks using standard risk assessment models. The findings offer valuable insights for public health authorities, environmental agencies, and the scientific community. By detailing contamination levels and potential health impacts, the study reinforces the necessity for targeted interventions—including enhanced environmental oversight, stricter food safety regulations, and public education campaigns—to mitigate exposure to heavy metals from dietary sources (Nkwunonwo *et al.*, 2020; Ibrahim *et al.*, 2024). The overall goal of these measures is to minimize human exposure to toxic metals through diet and promote safer food consumption practices.

1.1.4 SCOPE OF STUDY

The scope of this study involves the analysis of selected heavy metal contaminants in certain parts of the cattle – kidney, liver, intestines and tripe(popularly known as ‘shaki’ in West Africa) – collected from selected abattoirs in the Ovia North-East Local Government Area namely – University of Benin, University of Benin Teaching Hospital Cooperative, Ekosodin market and Oluku market. The area of study focuses mainly on the proximate and heavy metal content that may be found in the offal of the cattle. After purchasing the samples, they were stored appropriately to preserve the integrity of the sample before the commencement of the analysis. The analysis will show the percentage of heavy metal contaminants such as lead (Pb), cadmium (Cd), zinc (Zn) and chromium (Cr)/ copper (Cu) and it was carried out using Atomic Absorption Spectroscopy.

1.1.5 LIMITATIONS OF STUDY

This study faces several limitations that may affect the scope of its findings. First, the sample size and geographic coverage is limited, as offal samples were collected from the abattoirs in the Ovia North-East Local Government Area region, and it does not fully represent the broader population or take account for the varying environmental conditions. Heavy metal concentrations in offal vary significantly depending on local environmental pollution sources, animal feeding practices, and industrial activities, making it difficult to extrapolate results universally.

The cross-sectional study design restricts the ability to draw direct cause-and-effect conclusions between heavy metal intake from offal and specific health outcomes. In this study, factors such as the age, sex, metabolic differences of individuals, and combined exposure to other environmental contaminants were not comprehensively evaluated, which could affect the absorption, distribution, and overall health effects of heavy metals on consumption of the contaminated offal. These limitations highlight the importance of implementing continuous monitoring programs, conducting broader studies with increased sample sizes, and performing in-depth risk assessments to strengthen the evidence base and support the development of effective strategies for addressing health risks associated with heavy metal contamination in cow offal.

1.1.6 AIM AND OBJECTIVES

The aim of this study was to evaluate the proximate and selected heavy metal composition in the kidney, liver, intestines and tripe (popularly known as ‘shaki’)of cattles purchased from the, Ovia North-East Local Government Area, Edo State.

To achieve the above stated aim, the following objectives were set amongst others to:

1. Collect samples of kidney, liver, intestine and tripe (popularly referred to as ‘shaki’) from abattoirs within Ovia North-East Local Government area of Edo State.
2. Extract the concentrations of heavy metals using standard methods.
3. Determine the concentrations of heavy metals using an Atomic Absorption Spectrophotometer.
4. Compare results obtained with regulatory bodies and literature.
5. Carry out health risk assessment and make suitable recommendations.

1.2 LITERATURE REVIEW

1.2.1 Overview of beef production and Industry

Beef, obtained from cattle raised specifically for meat rather than milk, is a crucial part of the global food supply and significantly contributes to agricultural economies worldwide (FAO, 2023). Beef cattle are distinct from dairy cattle, as they are bred and managed with the primary goal of producing meat, not milk (USDA, 2021). The beef production process typically consists of several stages: cow-calf operations, where calves are born and reared; backgrounding or stocker phases, where young cattle are raised on forage to gain weight; and feedlot finishing, during which cattle are fed high-energy diets to optimize meat quality before slaughter (NCBA, 2022). This structured, multi-phase system is designed to efficiently produce high-quality beef that aligns with consumer expectations.

Economically, the beef industry is substantial. In the United States alone, beef production accounts for approximately 22% of total cash receipts from agricultural commodities, making it the largest and most influential sector in American agriculture (USDA ERS, 2023). The U.S. not only leads in global beef consumption but is also a top producer, supported by a unique system that separates beef and dairy production (ERS, 2023). The industry encompasses various segments—seedstock production**,** cow-calf operations**,** stocker/backgrounding**,** and feedlot finishing—which together form a complex supply chain that moves beef from farm to consumer (Cattlemen’s Beef Board, 2022).

Beyond meat, beef cattle provide essential by-products including leather, as well as ingredients used in pharmaceuticals and cosmetics, further enhancing their economic and industrial value (Texas A&M AgriLife Extension Service, 2020). The industry also applies selective breeding techniques to improve traits such as meat tenderness, feed efficiency, and disease resistance, promoting both sustainability and productivity (Van Eenennaam and Drake, 2012). Despite facing challenges such as market volatility**,** regulatory shifts, and supply chain disruptions, the beef industry remains a pillar of food security and agricultural output, especially in countries like the United States. States including Texas**,** Nebraska, and Kansas consistently lead in cattle numbers and beef production (USDA NASS, 2023).

1.2.2 Importance of beef quality

Beef quality is a crucial determinant of consumer satisfaction, market competitiveness, and the overall success of the beef industry (Scollan *et al*., 2006). The quality of beef is assessed based on several traits, including marbling (intramuscular fat), tenderness, flavor, juiciness, color, and texture, all of which influence consumer perception and preference (Hocquette *et al*., 2014). These sensory and physicochemical properties play a direct role in the eating experience, making them central to purchasing decisions (Miller, 2020). For example, marbling enhances both flavor and tenderness, making it one of the most valued indicators in beef grading systems (USDA AMS, 2017). The composition of fatty acids, particularly the presence of oleic acid, is also associated with better flavor and increased palatability, with higher levels linked to improved taste profiles (Smith *et al*., 2009).

Several factors influence beef quality, including genetics, breed, nutrition, and management practices (Savell and Cross, 1988). British breeds, such as Angus and Hereford, are often favored for their higher marbling and better tenderness when compared to some Continental breeds (Tatum *et al*., 2000). Feeding systems significantly impact quality; grain-based diets, especially over a 60–100-day finishing period, enhance marbling and fat content, thus improving flavor and texture

(Duckett *et al*., 2013). In contrast, forage-fed cattle tend to produce leaner beef with a distinct fatty acid profile that may appeal to health-conscious consumers (Daley *et al*., 2010). Additionally, post-slaughter handling—including minimizing stress, appropriate chilling, and meat aging practices—is critical for maintaining tenderness, color stability, and shelf life (Ferguson and Warner, 2008; AHDB, 2023).

1.2.3 Proximate Analysis of Offal parts

Offal**,** which includes the edible internal organs and entrails of animals such as the liver, heart, kidneys, brain, and tongue, is a nutritionally rich but often underutilized component of meat production. Despite its lesser popularity in mainstream diets, offal is a valuable dietary resource, offering high concentrations of essential nutrients often absent or limited in muscle meat (Ockerman and Basu, 2004).

A proximate analysis of offal commonly evaluates moisture, protein, fat, ash, and carbohydrate content—critical indicators of nutritional value. Offal typically contains higher levels of micronutrients, including vitamins and trace minerals, than conventional meat cuts. For example, the liver is particularly rich in protein, vitamin A, iron, and B-complex vitamins, while organs like the kidneys, heart, and brain contribute significantly to dietary intake of iron, zinc, and selenium (Gatellier *et al*., 2019).

- PROTEIN CONTENT: The protein content of offal generally ranges between 15% and 22%**,** depending on the specific organ and animal species. Organs with more connective tissue, such as the tongue and certain blood-rich tissues, tend to have elevated protein levels, although they may vary in amino acid composition compared to muscle tissue. Nevertheless, offal provides a complete protein source with essential amino acids in favorable ratios for human nutrition (Toldrá *et al*., 2016).

- FAT CONTENT: Fat content in offal varies significantly. Organs like the brain and tongue contain higher fat percentages, increasing their energy density and palatability, while leaner organs such as the heart and kidneys offer lower fat levels. This variability in fat composition influences the caloric value of different offal parts, which generally supply fewer calories than muscle meat due to differences in both fat and moisture content (Williams, 2007).
- MOISTURE CONTENT: Moisture content is consistently high in offal, often exceeding 70%, especially in organs such as the liver, heart, and kidneys. High moisture levels contribute to the tenderness and juiciness of these organs but also reduce their shelf life, making proper storage and processing essential (Jayathilakan *et al*., 2012).
- ASH CONTENT: The ash content, representing the total mineral content, is usually higher in offal than in skeletal muscle. This reflects the rich mineral profile of organs, which are important sources of iron, copper, zinc, and selenium—all critical for physiological processes such as oxygen transport, immune function, and enzymatic activity (Gatellier *et al*., 2019). These minerals are also more bioavailable in offal than in many plant-based foods, reinforcing its role in combating nutrient deficiencies (Pighin *et al*., 2016).

In addition to their nutritional value, offal products are economically advantageous and environmentally sustainable. They offer low-cost, high-nutrient food options, especially in regions where food insecurity and micronutrient deficiencies are common. Moreover, incorporating offal into human and animal diets reduces food waste and improves the efficiency of meat production systems (Seong *et al*., 2023).

In conclusion, offal is a nutrient-dense, cost-effective, and sustainable food resource**.** Its high-quality protein, essential minerals, beneficial fats, and rich vitamin profile make it a valuable component of both human and animal diets. Consumer education, improved processing, and ongoing research are key to increasing its acceptance and utilization. Promoting the use of offal can enhance nutrition security, support sustainable food systems, and add economic value to the meat industry.

1.2.4 HEAVY METALS

1.2.4.1 Common Heavy Metals and Their Characteristics

Heavy metals are a group of metallic elements known for their high atomic weight and density, and are often classified into essential and non-essential types based on their biological functions and toxicity (Järup, 2003). Essential heavy metals such as chromium (Cr^{3+}), copper (Cu^{2+}), cobalt (Co^{3+}), iron (Fe^{3+}), nickel (Ni^{2+}), manganese (Mn^{2+}), and zinc (Zn^{2+}) are necessary in trace amounts for normal biochemical and physiological functions in both plants and animals (Alloway, 2013). These metals serve as cofactors in enzymatic reactions, are involved in electron transport and redox regulation, and are essential for cellular structure and metabolism (Tchounwou *et al*., 2012).

However, even essential metals can become toxic when accumulated beyond physiological thresholds, potentially causing oxidative stress, enzyme inhibition, and metabolic dysfunction (Singh *et al*., 2011).

In contrast, non-essential heavy metals such as arsenic (As^{3+}), cadmium (Cd^{2+}), mercury (Hg^{2+}), and lead (Pb^{2+}) have no known biological role and are highly toxic, even at low exposure levels (Jaishankar *et al.*, 2014). These metals can induce carcinogenicity, neurotoxicity, immunotoxicity, and renal damage**,** especially through long-term exposure (IARC, 2012; EPA, 2023). Their persistence in the environment**,** bioaccumulate behavior, and ability to disrupt cellular signaling and repair mechanisms render them significant public health and ecological threats (Flora *et al.*, 2012).

Agencies such as the U.S. Environmental Protection Agency (EPA) and the International Agency for Research on Cancer (IARC) classify arsenic, cadmium, lead, and mercury as probable or known human carcinogens, further reinforcing their risk profile (EPA, 2023; IARC, 2012).

The distinction between essential and non-essential heavy metals is crucial for both environmental risk assessment and regulatory policy development. While trace amounts of essential metals support life, their excess poses health hazards, and hence must be carefully monitored in food, water, and soil (Alloway, 2013). Non-essential metals, in contrast, require strict regulation and active remediation efforts to prevent contamination and reduce population-level exposures (WHO, 2021).

A deeper understanding of the chemical properties, environmental behavior, and biological impacts of these metals enables scientists and policymakers to formulate strategies for pollution control, remediation, and health protection (Tchounwou *et al.*, 2012; Singh *et al.*, 2011).

1.2.4.2 Environmental and Health Implications

HEALTH IMPLICATIONS: Exposure to heavy metals such as lead, cadmium, and arsenic—common in contaminated offal—can lead to nephrotoxicity**,** damaging the kidneys and disrupting key metabolic pathways (Tchounwou *et al*., 2012; Jaishankar *et al*., 2014). Chronic ingestion of these metals through food can trigger oxidative stress, metabolic disruption, and increase the likelihood of diseases such as cancer, cardiovascular disorders, and neurodegenerative conditions (Flora *et al*., 2012; Hou *et al*., 2013).

Sensitive groups, including children and pregnant women, are particularly vulnerable due to bioaccumulation and biomagnification, which elevate exposure risk (WHO, 2021; Järup, 2003).The fact that heavy metals appear in offal reflects wider environmental contamination, originating from industrial emissions, mining, traffic pollution, and contaminated fertilizers or animal feeds (Ihedioha *et al*., 2014; Medhi *et al*., 2024).

ECOLOGICAL AND FOOD SAFETY CONCERNS: When contaminated offal is used as animal feed or fertilizer, it can introduce toxic metals into soils and water systems**,** perpetuating environmental pollution (Rodríguez-Eugenio *et al*., 2021; Flora *et al*., 2012). This cycle results in reduced soil quality, contamination of crops, and harm to aquatic ecosystems (Rodríguez-Eugenio *et al*., 2021; Ebong *et al*., 2024).Therefore, monitoring heavy metal concentrations in offal is essential not only for ensuring food safety but also for the management of environmental pollution (Adegbemi *et al*., 2020; Ihedioha *et al*., 2014).Regular surveillance and regulatory enforcement are crucial to control contamination sources, reduce bioaccumulation in livestock, and secure the safety of meat-derived products (Ebong *et al*., 2024; WHO, 2021).

1.2.5 REGULATORY STANDARDS AND GUIDELINES FOR BEEF QUALITY

Regulatory standards and guidelines for beef quality—both within Nigeria and internationally—are designed to guarantee the safety, nutritional integrity, and wholesomeness of beef products, safeguard public health, and support sustainable livestock practices (Codex Alimentarius Commission, 2024; EFSA, 2023).

In Nigeria, the National Agency for Food and Drug Administration and Control (NAFDAC) enforces Good Manufacturing Practice (GMP) regulations covering all stages of beef production—slaughtering, processing, packaging, and distribution—to ensure hygiene, contamination control, documentation, and quality assurance, thereby minimizing microbial and chemical hazards (NAFDAC Act Cap N1, 2004; NAFDAC GMP Guidelines, 2021).

The Nigerian Institute of Animal Science (NIAS) issues guidelines and codes of practice for animal husbandry, feed milling, and abattoir operations aimed at raising meat quality standards and promoting ethical livestock management (NIAS, 2025).

Recent government efforts include modernizing slaughter facilities, implementing compulsory hygiene certification for butchers, and delivering training programs across the beef supply chain to elevate production standards (Ministry of Livestock Development, 2025).

Internationally, beef quality standards are governed by key organizations like the Codex Alimentarius Commission, the World Organisation for Animal Health (OIE), and national authorities such as the U.S. Department of Agriculture (USDA) and the European Food Safety Authority (EFSA), which regulate beef production from farm to fork, covering welfare, slaughter methods, drug residue limits, microbiological standards, and labeling requirements (Codex Alimentarius, 2024; USDA FSIS, 2023; EFSA, 2023).

For example, Codex sets global standards for contaminant limits, hygiene practices, and traceability to assure consumer safety and confidence (Codex Alimentarius Commission, 2024).

The USDA Food Safety and Inspection Service (FSIS) applies stringent inspection and grading systems that evaluate beef based on marbling, maturity, and texture, factors that influence market value and consumer preference (USDA FSIS, 2023).

Similarly, the European Union enforces rigorous food safety and traceability laws to maintain high-quality beef production and facilitate international trade (EFSA, 2023).

Harmonizing Nigerian beef regulations with global standards is essential for boosting export potential and protecting domestic consumers. While Nigeria contends with infrastructure deficits, informal markets, and enforcement challenges, ongoing reforms aim to adopt best practices and strengthen institutions (Oluwafemi *et al.*, 2023; Ministry of Livestock Development, 2025.

Cooperative initiatives featuring government agencies, private sector participants, and development partners are working to upgrade slaughterhouse infrastructure, enforce hygiene protocols, and enhance awareness on safe meat handling from farm to retail (Ministry of Livestock Development, 2025).

These initiatives are projected to reduce foodborne illnesses, lengthen beef shelf life, and improve Nigeria’s competitiveness in regional and international beef markets (Oluwafemi *et al*., 2023; Ministry of Livestock Development, 2025).

In summary, robust regulatory frameworks and their diligent enforcement are vital to protect public health, ensure beef quality, and foster the sustainable development of Nigeria’s livestock sector (Oluwafemi *et al*., 2023; Ministry of Livestock Development, 2025).

1.2.5.1 Monitoring and Enforcement of Standards

Monitoring and enforcement of beef quality standards in Nigeria involve multiple agencies, mainly the National Agency for Food and Drug Administration and Control (NAFDAC), the Standards Organization of Nigeria (SON), and the Federal Ministry of Health. The NAFDAC FSAN Directorate inspects slaughterhouses, meat processors, and retail outlets to enforce Good Hygiene Practices and food safety regulations. These inspections assess sanitary conditions, contamination control, and the adequacy of both technical skills and equipment throughout the beef supply chain. However, persistent challenges—such as limited infrastructure, inadequate staffing, and informal market operations—can undermine these efforts, allowing unsafe meat conditions to persist.

Enforcement mechanisms include routine inspections, butcher certification, and oversight of slaughterhouse activities, but they are often hampered by understaffing, inconsistent protocols, and poor agency coordination. The significant role of informal markets and home slaughter further complicates compliance. To bridge these gaps, regulatory bodies collaborate with veterinary, public health, and consumer-protection stakeholders to deliver training, improve hygiene, and enforce regulations at market and abattoir levels (Oluwafemi *et al*., 2023).

1.2.6 HEAVY METAL ANALYSIS USING ATOMIC ABSOPRTION SPECTROSCOPY

Atomic Absorption Spectroscopy (AAS) is an analytical technique used to measure the concentration of elements by detecting the absorption of light by free atoms in the gaseous state. It detects the interaction of matter with radiation and the interaction of atoms absorbing radiation. AAS is a widely used and accepted technique capable of quantifying the concentration of trace and ultra-trace level of elements or metals in a wide variety of samples with good accuracy and acceptable precision. Atomic Absorption Spectroscopy is highly relevant in both scientific research and industrial applications because it provides accurate, sensitive, and specific analysis of metal elements.

1.2.6.1 HISTORICAL DEVELOPMENT OF ATOMIC ABSORPTION SPECTROSCOPY (AAS)

AAS (Atomic Absorption Spectroscopy) was developed as a result of the inefficiency of earlier analytical techniques - gravimetric analysis, titrimetric methods, colorimetry, flame photometry – which lacked sensitivity and specificity of trace metals or elements. The earliest spectroscopy was first discovered by Marcus Marci von Kronland in 1648 by analyzing sunlight as it passed through water droplets and thus creating a rainbow. After further analysis by several scientists, Robert Bunsen and Gustav Kirchhoff took a large step in defining the technique of atomic absorption spectroscopy (AAS), it was not widely utilized as an analytical technique except in the field of astronomy due to many practical difficulties.

In 1950, Sir Alan Walsh made a breakthrough in the development of Atomic Absorption Spectroscopy as a quantitative analytical technique. He realized that atoms in a flame could absorb light at specific wavelengths and this absorption could be used to measure the concentration of elements, the exact opposite of what flame emission spectroscopy did - which measured emitted light (Walsh, 1955). In 1955 as a result of the independent work of Walsh and C.T.J Alkemade modern AAS was introduced.

1.2.6.2 PRINCIPLES OF ATOMIC ABSORPTION SPECTROSOPY (AAS)

Atomic Absorption Spectroscopy (AAS) is based on the principle that free atoms in the ground state absorb light at specific wavelengths. The amount of light absorbed is directly proportional to the concentration of that element in the sample.

The Beer-Lambert Law relates the amount of light absorbed by a substance to its concentration:

$A=\varepsilon \cdot b \cdot c$

Where:

- **A** = Absorbance (no unit)
- **ε** = Molar absorptivity (L mol^{-1} cm^{-1}) — a constant for each element at a specific wavelength
- **b** = Path length (cm) — how far the light travels through the sample
- **c** = Concentration (mol/L) of the absorbing species

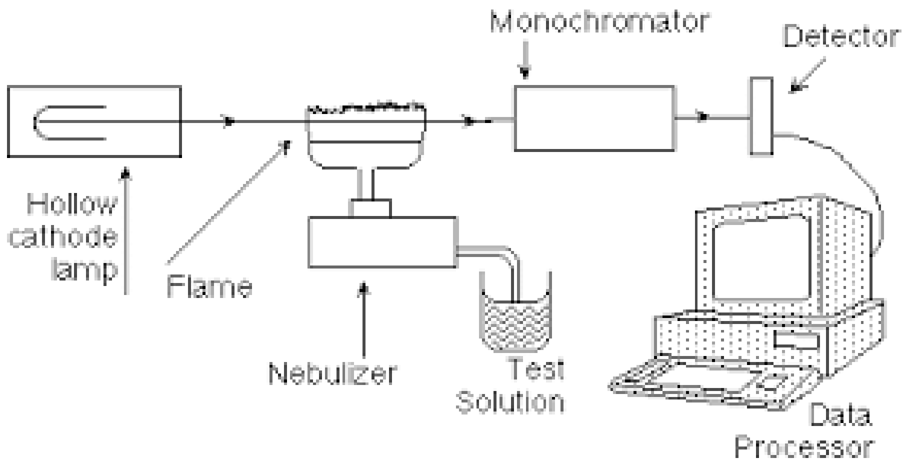

Figure 1.1: Schematic diagram of an atomic absorption spectrometer.

Source: Google photos (https://share.google/images/EYXo0izzAaIyuJgyP)

CHAPTER TWO

MATERIALS AND METHODS

2.1 MATERIALS

2.1.1 Apparatus

- 100mL volumetric flasks
- Whatman No. 42 filter Paper
- Acid-washed polyethylene bottles
- Atomic Absorption Spectrophotometer (Buck Scientific, Model: 210VGP)
- Vacuum Oven (NewLife Medical England, Model: DHG-9023A)
- Fume Hood (Biobase, Model: FH1800)
- Blender (Sharp Blender, Model: EM-11)
- Pre-ignite and tared crucibles
- Hot plate (Infitek, Model: HPT-320-5B)
- 250mL Beakers
- 10mL Measuring Cylinder
- 250mL Conical flasks
- Glass rods
- Plastic funnels

2.1.2 Reagents

- Deionized water (H_2O)
- Certified standard solution of heavy metals: cadmium (Cd^{2+}) and zinc (Zn^{2+}),
- Concentrated nitric acid (HNO_3)

- Concentrated perchloric acid ($HClO_4$)

2.2 METHODOLOGY

2.2.1 SAMPLE LOCATION

The samples used were sourced from three locations in Ovia North-East local government area of Edo State. Ovia North-East Local Government Area is one of the four Local Government Area Councils in the city of Benin. The samples were sourced from abattoirs located in the University of Benin, University of Benin Teaching Hospital (UBTH) Cooperative and Ekosodin market.

SAMPLE COLLECTION AND PREPARATION

Fresh samples of cow offal – liver, kidney, tripe (popularly referred to as shaki) and intestine – were purchased from the various abattoirs on a market day. All collected samples were stored in clean dry polythene bags and labelled correctly, afterwards the samples were stored in the freezer to be preserved. Information on the grazing location, age and gender of the slaughtered cow were not known because the butcher men were semi-literate. The samples were dried in the laboratory oven at 200°C and blended for acid digestion to commence. The samples were ground into a fine powder using an electric blender and stored in well-labeled sample bottles used for acid digestion.

Table 2.1: Sample description and source

S/N	**Sample code**	**Sample description**	**Source of sample**
1	UN-K	Kidney	University of Benin (UNIBEN)
2	UN-I	Intestine	University of Benin (UNIBEN)
3	UN-L	Liver	University of Benin (UNIBEN)
4	UN-S	Shaki	University of Benin (UNIBEN)
5	UB-K	Kidney	University of Benin Teaching Hospital (UBTH)
6	UB-I	Intestine	University of Benin Teaching Hospital (UBTH)
7	UB-L	Liver	University of Benin Teaching Hospital (UBTH)
8	UB-S	Shaki	University of Benin Teaching Hospital (UBTH)
9	EK-K	Kidney	Ekosodin
10	EK-I	Intestine	Ekosodin
11	EK-L	Liver	Ekosodin
12	EK-S	Shaki	Ekosodin

Figure 2.1: Sample preparation at the laboratory.

2.2.3 SAMPLE DIGESTION

8mL of concentrated nitric acid (HNO_3) was added to 1g of the dried sample placed in a 100mL beaker, 2mL of perchloric acid ($HClO_4$) was added to the mixture. The digestion was carried out by heating the mixture until the brown nitrogen dioxide fumes turned white, indicating near completion of oxidation. After cooling, the mixture was filtered through Whatman No. 42 filter paper, and the filtrate was diluted to 100mL with distilled water in the 100mL volumetric flask. All samples were stored in acid-washed containers until they are ready for analysis. Heavy metal concentrations (Cd, Zn) were then determined using an atomic absorption spectrophotometer. The digestion procedure was based on the method described by Luo *et al*. (2021), with slight modifications.

Figure 2.2: Sample digestion at the laboratory.

2.2.4 HEAVY METAL DETERMINATION USING ATOMIC ABSORPTION SPECTROSCOPY (AAS)

The digested meat samples were analyzed in the laboratory at the University of Benin. Determination of the concentration of heavy metals (Cd, Zn) was done using Atomic Absorption Spectroscopy (AAS) following standard operating procedures. The atomic absorption spectrometer was calibrated using standard solutions of known metal concentrations along with reagents blank. Each sample was analyzed carefully to ensure reliability, and then mean values of the concentrations was reported.

2.2.5 DATA ANALYSIS

Heavy metal concentrations were initially expressed in mg/L and subsequently converted to mg/kg. Data analysis included descriptive statistics and comparison with permissible limits set by the Codex Alimentarius Commission (CODEX) and the Joint FAO/WHO Expert Committee on Food Additives for heavy metals in offal of cattle.

CHAPTER THREE

3.1 RESULTS AND DISCUSSION

The quantitative data derived from the spectroscopic analysis of heavy metal concentrations (mg/L) in the cow offal samples gotten from various locations including University of Benin abattoir, University of Benin Teaching Hospital (UBTH) abattoir and Ekosodin abattoir are presented in Table 3.1 below.

The spectroscopic analysis of the heavy metal content revealed the presence of zinc in all the samples, with concentrations ranging from 47.00 – 197.00 mg/kg (Using the laboratory digestion scheme,1.00 g tissue digested and made up to 100.0 mL) (Table 3.1).

In contrast, cadmium was detected only in a few samples (UB-I, UB-S, EK-K) with a concentration of 1.0 mg/kg under the digestion scheme employed, while it was below the detectable limit in the remaining preparations.

The highest concentration of Zinc was observed in the kidney gotten from Ekosodin abattoir with a concentration of 197.00mg/kg (fw) and the lowest concentration of zinc was measured in the intestine samples.

For Cadmium, the highest concentration was observed in the intestine and shaki gotten from the University of Benin abattoir and in the kidney gotten from Ekosodin abattoir.

Table 3.1: Quantitative analysis of selected metal concentrations (mg/kg) in prepared samples

S/N	Sample code	Concentrations			
		Zn (mg/L)	Converted Zn (mg/kg fw)	Cd (mg/L)	Converted Cd (mg/kg fw)
1	UN-K	0.96	96.00	ND	ND
2	UN-I	0.56	56.00	ND	ND
3	UN-L	0.81	81.00	ND	ND
4	UN-S	0.98	98.00	ND	ND
5	UB-K	0.97	97.00	ND	ND
6	UB-I	0.47	47.00	0.01	1.00
7	UB-L	1.69	169.00	ND	N
8	UB-S	0.87	87.00	0.01	1.00
9	EK-K	1.97	197.00	0.01	1.00
10	EK-I	0.99	99.00	ND	ND
11	EK-L	1.09	109.00	ND	ND
12	EK-S	0.87	87.00	ND	ND

3.1.1 DISCUSSION

ZINC (Zn)

The analysis demonstrated significantly higher zinc concentrations in the liver and kidney relative to intestinal tissues. This finding highlights the preferential accumulation of zinc in metabolically active organs responsible for detoxification and homeostasis. Studies on zinc accumulation in cow offal have demonstrated elevated zinc levels in both the liver and kidney, reaffirming these organs as principal sites of trace metal deposition (Akele *et al.,* 2019; Biel *et al.*, 2019; Obioha, 2019).

This organ-specific distribution likely reflects psychological roles: the liver acts as a major site for metal storage and homeostasis regulation, and the kidney participates in filtration and excretion of excess metals (Ihedioha & Onianwa, 2014; Okorafor *et al.,* 2015). At molecular level, zinc associates with low molecular weight metal-binding proteins including metallothioneins, which are relatively abundant in hepatic and renal tissues and mediate intracellular sequestration and detoxification.

The organ-specific accumulation observed in this study may also reflect broader environmental influences. Animals grazing on soils or forage contaminated by agricultural inputs, industrial effluents, or mining-derived particulates exhibit increased zinc uptake and higher liver and kidney burdens (Akele *et al.,* 2022). Variations in publications may be attributed to differences in environmental exposure, supplementation practices, breed, age, and sampling design across regions of Nigeria.

Ten of 12 samples exceeded the Codex Alimentarius reference level for edible offal (80 mg/kg fw), with kidneys and livers showing the highest means (kidney mean 130.0 mg/kg; liver mean 119.7 mg/kg). The observed tissue distribution (liver and kidney > spleen/intestine) aligns with previous Nigerian and regional reports that metabolically active organs accumulate higher Zn concentrations.

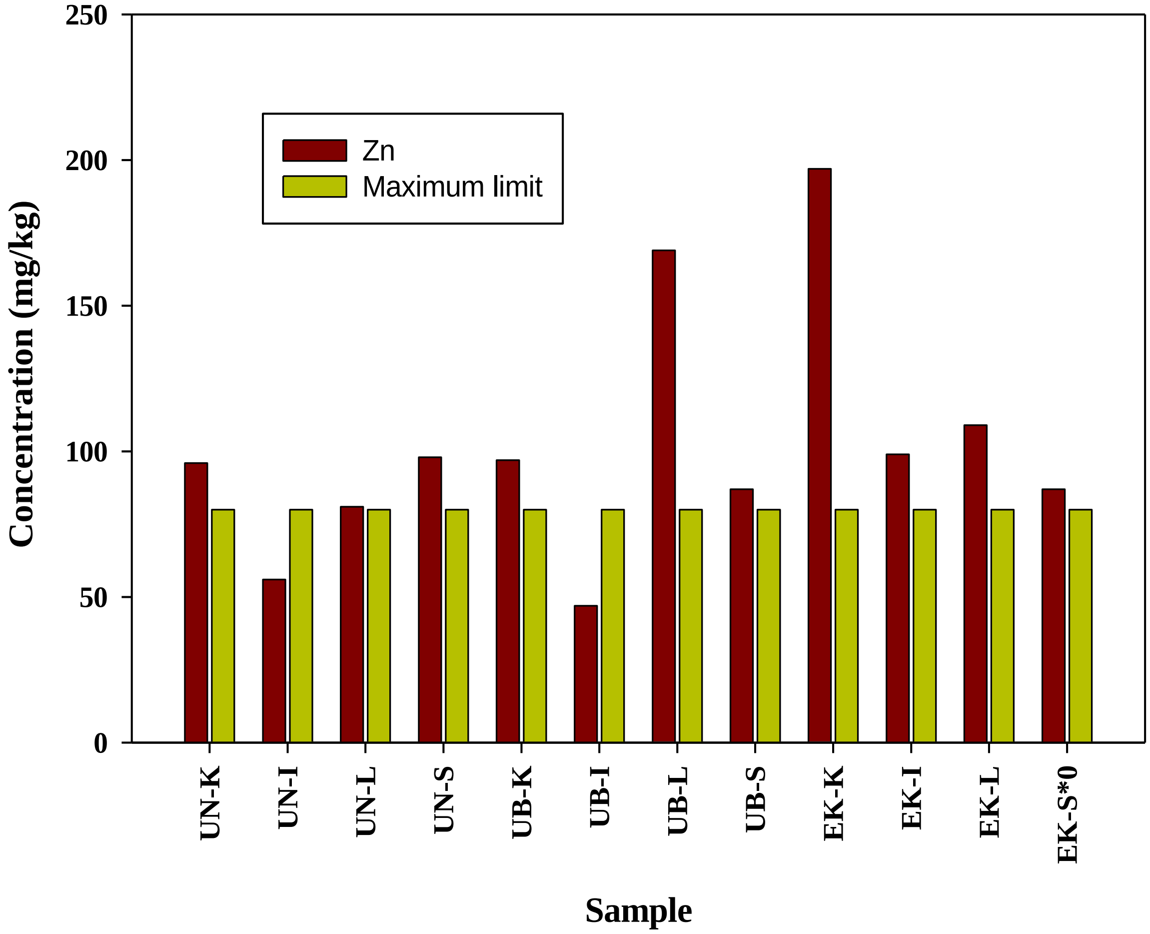

Figure 3.1: Bar chart of concentrations of zinc (mg/kg) obtained from the various cow offal samples.

While this study provides important insight into zinc distribution across bovine tissues, several methodological limitations should be acknowledged. The sampling frame did not account for management and environmental factors such as grazing practices of the cattle, their grooming or husbandry conditions and the specific locations where the animals were reared.

From a food-safety perspective, the elevated zinc levels in edible offal have relevance for dietary exposure assessments, particularly in populations with high offal consumption or where regulatory monitoring is limited. Although zinc is an essential nutrient, chronic high intake from concentrated organ sources could, in some circumstances, exceed recommended tolerable intakes or interact with absorption of other micronutrients; accordingly, routine monitoring and context-specific risk assessment are advisable. Future studies should therefore couple multi-element analysis with dietary intake modeling to quantify potential consumer risks.

Cadmium (Cd)

Cadmium was undetected in most bovine tissues analyzed; however, three samples (UB-I, UB-S, EK-K) yielded measurable concentrations of 1.0 mg/kg fresh weight (fw), which converts to approximately 0.01 mg/L. Although the detection frequency was low, the observed values warrant attention. The Codex Alimentarius has proposed maximum levels for cadmium in offal at 0.5 mg/kg for liver and 1.0 mg/kg for kidney (Codex Alimentarius Commission, 2019). Thus, the concentrations detected in this study approach or equal these regulatory thresholds, particularly for kidney samples.

Cadmium is a non-essential element known for its cumulative toxicity. It tends to bioaccumulate in the liver and kidney, with chronic exposure linked to nephrotoxicity, bone demineralization, and cardiovascular disorders (Charkiewicz, 2023). To protect public health, the Joint FAO/WHO Expert Committee on Food Additives (JECFA) established a Provisional Tolerable Monthly Intake (PTMI) of 25 µg/kg body weight (WHO, 2011). A conservative exposure estimate shows that a 50 g portion of offal at 1.0 mg/kg would provide 50 µg of cadmium, meaning daily consumption over a month could reach the PTMI for a 60-kg adult. This suggests that frequent consumers of bovine offal may be at risk of cumulative cadmium exposure.

Comparisons with regional studies show a similar pattern. Ihedioha and Okoye (2014) reported cadmium concentrations in Nigerian cow meat and offal ranging from 0.02 to 0.47 mg/kg, while Akele *et al*. (2022) observed levels of 0.01 – 0.93 mg/kg in bovine liver and kidney from slaughterhouses in southern Nigeria. These values, although variable, fall within the same order of magnitude as the present findings, indicating that cadmium contamination is sporadic but recurrent in Nigerian livestock. Internationally, Chunhabundit (2016) highlighted that dietary cadmium exposure from contaminated animal products is a significant contributor to overall intake, especially in populations with high offal consumption.

Taken together, these results indicate that while most samples from Benin City were below detection limits, the sporadic exceedances observed are consistent with previously reported values in Nigeria and other regions. Such findings underscore the need for continuous surveillance of cadmium in bovine tissues, particularly in organs like the liver and kidney, and for interventions to minimize environmental contamination of the food chain.

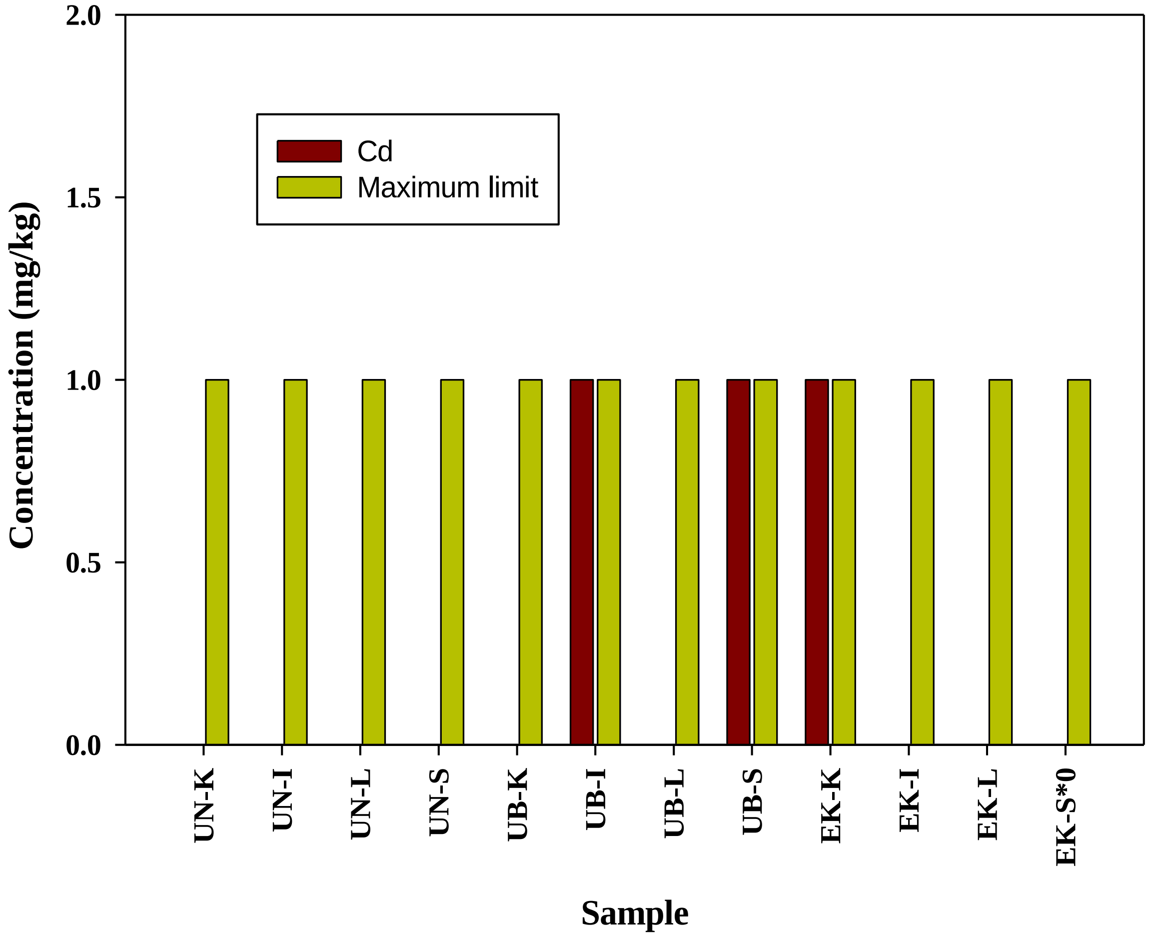

Figure 3.2: Bar chart of concentrations of cadmium (mg/kg) obtained from the various cow offal samples showing the maximum limit of consumption.

3.2 RESULTS

The quantitative results of the spectroscopic analysis of heavy metal concentrations (mg/kg) in cow offal obtained from the University of Benin abattoir, University of Benin Teaching Hospital (UBTH) abattoir, and Ekosodin abattoir are presented in Table 3.2.

Zinc (Zn) was detected in all the examined samples, with concentrations ranging from 52.00 – 154.00 mg/kg fresh weight (fw) (Table 3.2). The highest Zn concentration (154.00 mg/kg) was recorded in kidney samples from Ekosodin abattoir, whereas the lowest concentrations were observed in intestinal samples gotten from University of Benin Teaching Hospital (UBTH) abattoir.

Cadmium (Cd), on the other hand, was detected only in selected samples (UB-I, UB-K, EK-K, EK-L, EK-S), with a concentration of 1.00 mg/kg in all samples except EK-L and EK-S having a concentration of 0.00 mg/kg. In all other preparations, Cd was below the detectable limit. The highest Cd levels were observed in the intestine and kidney samples obtained from the University of Benin abattoir, as well as in the kidney from Ekosodin abattoir.

Table 3.2: Quantitative analysis of selected metal concentrations (mg/kg) in prepared samples.

S/N	**Sample Code**	**Concentrations**			
		Zn (mg/L)	**Converted Zn (mg/kg fw)**	**Cd (mg/L)**	**Converted Cd (mg/kg fw)**
1	UN–K	0.91	91.00	ND	ND
2	UN-I	1.00	100.00	ND	ND
3	UN-L	0.86	86.00	ND	ND
4	UN-S	0.92	92.00	ND	ND
5	UB-K	0.91	91.00	0.01	1.00
6	UB-I	0.52	52.00	0.01	1.00
7	UB-L	1.01	101.00	ND	ND
8	UB-S	0.75	75.00	ND	ND
9	EK-K	1.54	156.00	0.01	1.00
10	EK-I	1.21	121.00	ND	ND
11	EK-L	0.91	91.00	0.00	0.00
12	EK-S	0.93	93.00	0.00	0.00

3.2.1 DISCUSSION

ZINC (Zn)

Zinc was detected in all bovine tissue samples analyzed with analytical concentrations of 0.52–1.54 mg/L, which correspond to 52.0–154.0 mg/kg fresh weight (fw) when converted using the laboratory digestion scheme (1.00 g → 100.0 mL). The overall mean zinc content (95.6 mg/kg fw) is above the Codex Alimentarius reference level commonly used for edible offal (80 mg/kg fw) and also above the Codex muscle benchmark (50 mg/kg fw) for most individual samples (Codex Alimentarius Commission; Ihedioha et al., 2014).

Kidney and liver showed the highest mean concentrations (kidney mean 112.0 mg/kg; liver mean 92.7 mg/kg), consistent with widely observed tissue distribution patterns in which metabolically active organs concentrate essential and non-essential metals more than other tissues (Ogbomida et al., 2018; Ihedioha & Okoye, 2014). The highest value observed (EK–K = 154.0 mg/kg fw) is nearly twofold higher than the Codex offal screening value and therefore represents a potential screening-level concern, particularly for consumers who frequently include kidneys or livers in their diet.

From a toxicological perspective, zinc is an essential micronutrient with a relatively wide safety margin compared with toxic non-essential metals, but excessive dietary zinc can produce adverse effects (e.g., gastrointestinal upset, interference with copper absorption) and regulatory bodies set tolerable upper intake guidance to prevent chronic excess. The Tolerable Upper Intake Level (UL) for adults is commonly cited at 40 mg/day (Institute of Medicine / NIH ODS) or 40–45 mg/day in other summaries; dietary exposure assessment should relate tissue concentrations to portion sizes and meal frequency to determine intake relative to ULs (Institute of Medicine, 2001; NIH ODS, 2022).

Regional studies provide useful comparators. Several Nigerian surveys report variable zinc concentrations in offal and muscle: Ogbomida et al. (2018) found zinc values in free-range animals from Benin City that were generally below Codex limits but with notable tissue-specific variability linked to proximity to municipal waste and contamination sources; Ihedioha et al. (2014) reported ranges for Zn in urban Nigerian bovine tissues that are broadly comparable to the lower portion of the present results when unit conversions and sampling schemes were considered. Where differences arise (e.g., EK–K = 154.0 mg/kg), they may reflect local contamination pathways (environmental pollution, contaminated feed or water, veterinary inputs), or batch/sample heterogeneity and highlight the importance of increased surveillance and source tracing.

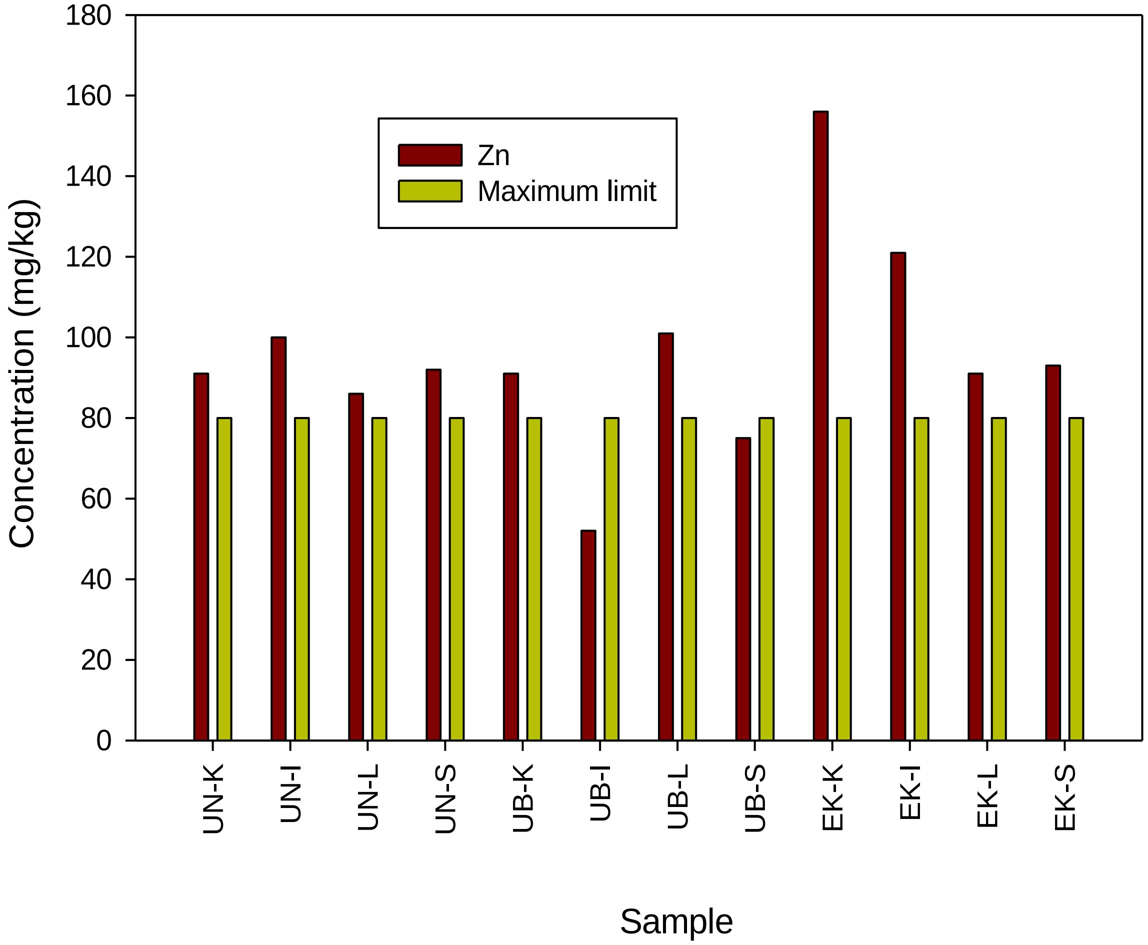

Figure 3.3: Bar chart of concentrations of zinc (mg/kg) obtained from the various cow offal samples showing the maximum limit of consumption.

CADMIUM (Cd)

In this study, cadmium was not detected (ND) in most of the bovine tissue samples analyzed, except for trace concentrations of 0.01 mg/L in UB-K and UB-I. When converted from the digestion ratio (1 g tissue in 100 mL digest), this corresponds to approximately 1.0 mg/kg fresh weight (fw). The concentrations detected are of concern given that cadmium is a non-essential and toxic heavy metal with high bioaccumulation potential in the kidney and liver of food animals (Charkiewicz, 2023).

According to the Codex Alimentarius Commission (2019), the maximum permissible level of cadmium is 0.5 mg/kg in bovine liver and 1.0 mg/kg in kidney. The European Commission (EC, 2006) sets similar thresholds of 0.5 mg/kg for liver and 1.0 mg/kg for kidney. Nigeria currently adopts Codex guidelines for contaminants in food (SON, 2018). Therefore, the cadmium levels of 1.0 mg/kg observed in this study are at the regulatory limit for bovine kidney and exceed the permissible level for liver, raising potential food safety concerns if such tissues are frequently consumed.

Cadmium exposure is associated with renal dysfunction, skeletal damage, and cardiovascular disorders, and the Joint FAO/WHO Expert Committee on Food Additives (JECFA) has established a Provisional Tolerable Monthly Intake (PTMI) of 25 µg/kg body weight (WHO, 2011). For instance, consumption of a 50 g portion of kidney at 1.0 mg/kg would provide 50 µg cadmium, which alone accounts for the monthly tolerable intake for a 60-kg adult. This suggests that even low but repeated dietary exposure could pose a chronic health risk.

Comparison with literature reveals similar findings. Ihedioha and Okoye (2014) reported cadmium levels ranging from 0.02 to 0.47 mg/kg in cow meat and offal in southeastern Nigeria, while Akele et al. (2022) found concentrations between 0.01 and 0.93 mg/kg in bovine kidney and liver from southern Nigeria. Both studies indicate that cadmium contamination in Nigerian livestock is sporadic but recurrent, likely linked to environmental pollution from mining, waste disposal, and agricultural inputs. Globally, Chunhabundit (2016) emphasized that cadmium from offal remains an important contributor to dietary cadmium intake in populations where organ meats are commonly consumed.

Taken together, the results suggest that cadmium contamination in bovine offal from Benin City is relatively low but not negligible, since isolated samples reached regulatory thresholds. These findings align with Nigerian and international studies and highlight the importance of routine monitoring to prevent excessive human exposure through dietary pathways.

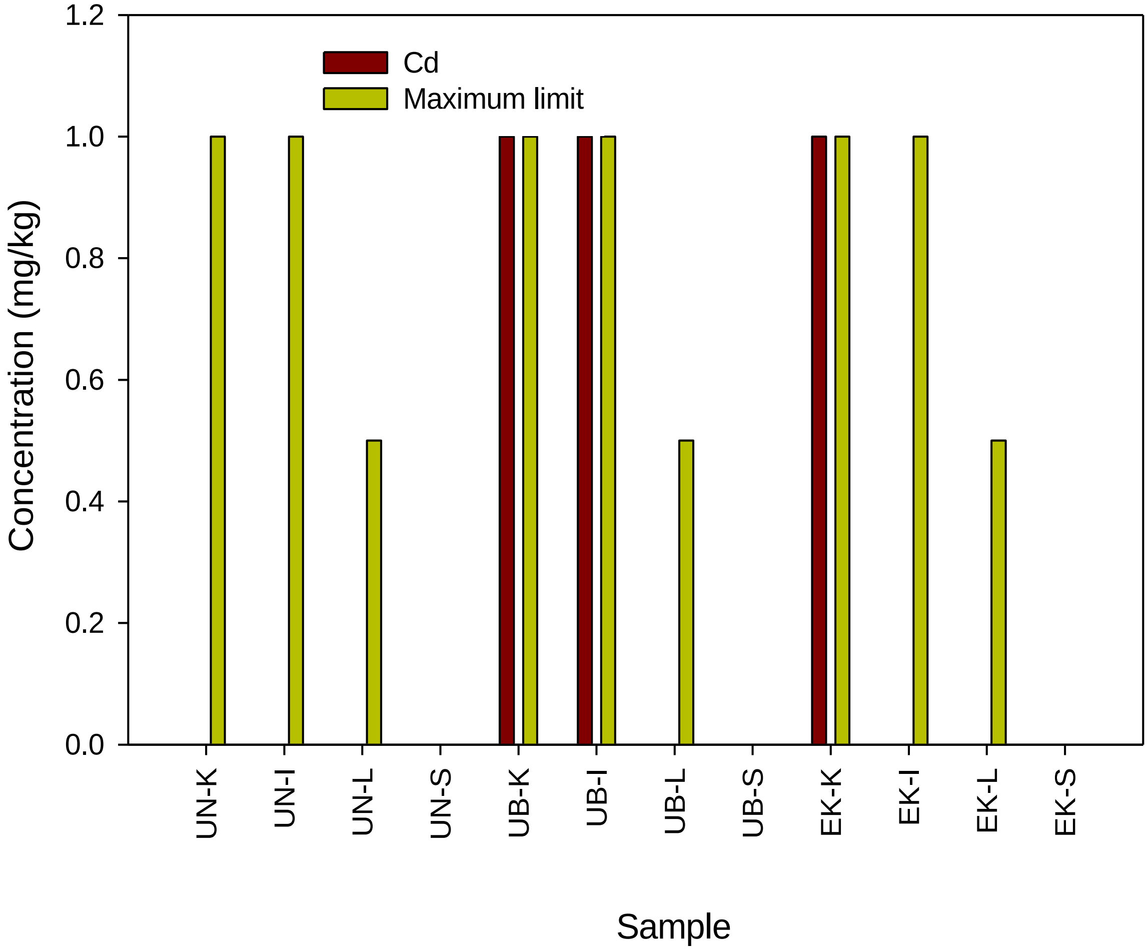

Figure 3.4: Bar chart of concentrations of cadmium (mg/kg) obtained from the various cow offal samples showing the maximum limit of consumption.

3.3 IMPLICATION OF FINDINGS

Heavy metals such as cadmium and zinc, though naturally occurring, can pose serious health risks when present in excess. Their impact varies across different age groups and health conditions, making awareness and prevention crucial.

In pregnant women, cadmium readily crosses the placenta and disrupts fetal growth and zinc metabolism in placental tissues, thereby impairing nutrient transport essential for fetal development (Young *et al.,* 2020). Even low maternal cadmium levels during early or late pregnancy have been associated with significantly reduced birthweight and increased risk of small-for-gestational-age infants (Zinia *et al.,* 2023).

In babies and young children, prenatal and early-life cadmium exposure is linked to adverse out comes including low birth weight, impaired fetal growth, trace element deficiencies, and developmental malformations (Young *et al.,* 2020). Cadmium's interference with zinc and copper homeostasis during perinatal stages may contribute to developmental and immune dysfunction in infants (Ishitobi *et al.,* 2005).

In older adults, cumulative cadmium exposure is strongly associated with progressive kidney dysfunction and bone demineralization. Cadmium accumulates in renal cortex tubule cells, inducing oxidative stress, apoptosis, and irreversible declines in glomerular filtration rate (Aaseth *et al.,* 2021; Zhang *et al.,* 2025). These renal effects often contribute to skeletal weakening and increased fragility (Aaseth *et al.*, 2021; Zhang *et al.,* 2025).

Chronic cadmium exposure is linked to a spectrum of long-term health risks, including renal toxicity, cardiovascular disease, and cancer (Young *et al.*, 2020). Cadmium is also a known endocrine disruptor that perturbs zinc transporters, impairing zinc absorption and exacerbating cytotoxicity even when dietary zinc is adequate (Cirović *et al.,* 2024).

3.4 RECOMMENDATIONS

Animal offal such as liver and kidney often accumulates heavy metals, especially cadmium and lead, which may pose health risks if consumed frequently (Chunhabundit, 2016). Research shows that offal can contain levels of these metals high enough to present carcinogenic and non-carcinogenic risks, particularly for children and adults who consume them regularly (Emurotu *et al.,* 2024).

a) To minimize exposure, frequent intake of offal from unverified sources should be limited.
b) Vulnerable groups such as pregnant women, children, and the elderly need extra caution, as their bodies are more sensitive to toxic effects (Zhao *et al.,* 2024).
c) Proper washing and thorough cooking can reduce surface contaminants but cannot eliminate metals embedded in tissues.
d) Therefore, sourcing meat from trusted suppliers with safety inspections remains crucial (Njoga *et al.,* 2021).
e) Community awareness is equally important.

When consumers demand safer food practices, sellers are pressured to ensure compliance with regulatory standards, ultimately reducing exposure and protecting public health.

3.5 CONCLUSION

Limiting frequent offal consumption, exercising caution among vulnerable groups, ensuring proper sourcing, and raising community awareness are key strategies to reduce heavy metal exposure. While cooking cannot remove embedded metals, choosing regulated suppliers and demanding safer food practices can significantly protect public health and the environment. Evidence from recent studies confirms that dietary offal is a major pathway of cadmium and zinc intake, reinforcing the importance of preventive action at both individual and community levels.

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