CARCINOGENIC AND NON-CARCINOGENIC RISK ASSESSMENT OF HEAVY METALS IN WATER AND SEDIMENTS FROM AUTOMOBILE SPARE PART AND RECYLING MARKET,IPATA OLOJE ILORIN

BY

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CERTIFICATION

This is to certify that this project work was carried out and reported by **ADENIYI OLAMIDE TIMILEYIN** with Matric **ND/23/SLT/PT/0505** in the Department of Science Laboratory Technology (SLT), Institute of Applied Sciences (IAS) and has been read and approved as meeting the requirements for the award of National Diploma (ND).

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DEDICATION

This project work is dedicated to GOD Almighty the giver of life, knowledge, wisdom, and understanding to succeed in our field of study and also to our beloved parents who have made the journey so easy and successful one, who continually provide their moral, spiritual, emotional, and financial support.

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ABSTRACT

This study evaluates the sources and health risks of heavy metals in soil and water samples from Ipata-Oloje spare part market in Ilorin, Nigeria. Concentrations of Pb, Cd, Cr, Co, and As were analyzed using Atomic Absorption Spectrometry. Results showed higher heavy metal levels in sediment than in water, with Pb and Co exhibiting the highest concentrations in soil and water, respectively.

Risk assessment revealed that the Average Daily Intake (ADI) via ingestion exceeded dermal absorption for all metals, with Pb posing the highest ingestion risk and Cd the highest dermal risk. Ecological risk analysis indicated no significant environmental threat from soil contamination. The non-carcinogenic Hazard Index (HI) for both soil and water was below 1.0, suggesting negligible risk. Carcinogenic risk via ingestion was within acceptable limits (<1.0E-6), but arsenic exceeded the threshold for dermal exposure, indicating a potential cancer risk from prolonged skin contact with contaminated soil.

The elevated metal levels were attributed to anthropogenic activities, particularly from automobile spare parts and recycling operations. The study recommends further research using mass flux models to better understand heavy metal transport and dilution dynamics in the area.

CHAPTER ONE

1.0 INTRODUCTION

Heavy metals are naturally occurring elements with high atomic weights and densities that are at least five times greater than that of water. Despite their utility in industrial and technological applications, several heavy metals are known for their toxicity and potential to bioaccumulate in human tissues and the environment. This study focuses on assessing the presence and concentration of heavy metals in automobile parts sold and recycled at Ipata Market in Ilorin, Nigeria, a prominent hub for vehicle spare parts and informal automobile-related activities.

This chapter introduces the core focus of the research by outlining the scope, rationale, and structure of the study. It begins with a detailed background to contextualise the concept of heavy metals, their relevance to environmental and public health, and the significance of their investigation within automobile markets. It also presents a review of global, African, and Nigerian literature on heavy metal contamination in automotive parts, highlighting current gaps and justifying the need for the present investigation. Finally, the chapter concludes with a statement of research purpose, underlining the importance of adopting a localised yet scientifically rigorous approach to evaluating heavy metal contamination in urban trade environments.

1.1 BACKGROUND OF THE STUDY

Heavy metals are a group of elements that include both essential (e.g., iron, zinc, copper) and non-essential (e.g., lead, cadmium, mercury) metals, many of which become toxic when their concentrations exceed physiological thresholds. These elements are nonbiodegradable and tend to persist in the environment, thereby making their accumulation in air, water, soil, and biota a serious concern (Heidari et al., 2021). Industrialisation, urbanisation, and the increased use of metal-containing components in manufacturing and automotive sectors have led to a global rise in environmental heavy metal pollution.

Heavy metals such as lead (Pb), cadmium (Cd), chromium (Cr), nickel (Ni), and mercury (Hg) are commonly found in automotive parts such as batteries, brake pads, engine components, radiators, and paint coatings (Manasfi et al., 2021). Over time, these metals can leach into the environment during use, repair, dismantling, or improper disposal—especially in markets and workshops with minimal environmental controls.

The toxic effects of heavy metals on human health are well documented. Lead, for instance, is a potent neurotoxin, especially dangerous to children, and is associated with developmental disorders, cognitive decline, and renal dysfunction (Obeng-Gyasi, 2019). Cadmium can damage the kidneys and bones and is classified as a human carcinogen (IARC, 2020). Chromium (particularly Cr(VI)) and nickel are also associated with

respiratory issues and skin sensitisation, while long-term exposure to mercury affects the nervous, digestive, and immune systems (Islam et al., 2018).

Environmentally, heavy metals contaminate soil, disrupt microbial activities, and affect plant growth. Runoffs from automotive waste or improperly discarded parts contribute to the accumulation of toxic metals in urban and peri-urban soils, thereby posing risks to local agriculture and water supplies. In areas without adequate regulatory oversight, informal automobile markets often function as unmonitored pollution hotspots.

Automobile components are an under-examined yet critical source of heavy metal pollution, particularly in developing nations where vehicle importation, dismantling, and part reuse are extensive and largely informal. Markets such as Ipata in Ilorin operate as secondary centres for automobile maintenance and disposal, where components are handled, repurposed, and discarded without strict environmental regulation. Studying heavy metals in these parts is essential for three key reasons.

Firstly, it provides baseline data for environmental health and pollution risk assessments, especially in urban areas where direct human exposure to metals may be high. Secondly, it aids in formulating better policies for waste management and occupational health in the informal sector. Lastly, understanding the metal content of these components supports broader efforts to assess the environmental footprint of automotive waste in the context of global climate change mitigation and resource sustainability (Adusei et al., 2020).

Globally, several studies have assessed heavy metal contamination in vehicular components. For instance, research by Lyu et al. (2022) in China demonstrated the significant presence of Pb, Cr, and Cd in brake and tyre wear particles, contributing to urban air and soil pollution. Similarly, Alghamdi et al. (2021) examined the release of metals from used engine oil and lubricants, highlighting their role in long-term soil contamination. These studies affirm that vehicles—both in active use and in scrap form— represent mobile sources of persistent environmental pollutants.

Recent advances in spectroscopy and analytical chemistry have improved the detection of metal contaminants in automotive waste. However, while such studies are prevalent in Europe, North America, and East Asia, similar research in sub-Saharan Africa remains limited and underfunded. This geographic gap in research reinforces the importance of studies conducted in Nigeria and other African countries, where informal automobile reuse and recycling practices are widespread but poorly regulated.

In the African context, growing urbanisation and dependence on imported used vehicles have intensified concerns about the environmental risks posed by automobile-derived pollutants. A study in Ghana by Doyi et al. (2021) evaluated heavy metal accumulation in soils around scrap yards and found elevated concentrations of Pb and Cr. In South Africa, Mngomezulu and Monyai (2019) assessed leachates from dismantled car batteries and discovered hazardous levels of Cd and Pb entering the soil and water systems.

Moreover, the informal nature of vehicle dismantling across Africa results in direct exposure of workers to heavy metals through inhalation, ingestion, and dermal absorption. Studies have highlighted the need for better environmental monitoring and health surveillance of workers in auto-part markets and scrap yards (Ochieng et al., 2020).

Despite increasing awareness, regulatory enforcement remains weak in many African nations. Often, limited institutional capacity and lack of public awareness hinder the implementation of sustainable practices. Research efforts in African countries are therefore increasingly focused on generating localised evidence to inform policy and occupational safety standards.

Nigeria, as one of Africa's largest automobile markets, is heavily reliant on the importation of used vehicles and spare parts. Informal markets such as Ladipo (Lagos), Nkpor (Anambra), and Ipata (Ilorin) serve as central hubs for the sale, modification, and disposal of these components. Several studies have begun to explore the environmental health implications of such markets.

Iwegbue et al. (2019) analysed metal concentrations in vehicle brake pads and found high levels of copper, zinc, and lead. Similarly, Olatunji et al. (2022) investigated heavy metal contamination around auto-mechanic workshops in Ibadan and reported soil Pb levels exceeding WHO safety limits. In Kano, Akinola et al. (2023) detected elevated

levels of chromium and cadmium in roadside dust samples collected near vehicle repair hubs.

These studies collectively point to a pattern of heavy metal pollution associated with automobile activities. However, the regional variability of Nigeria's markets—due to differences in soil composition, trade dynamics, and climate—necessitates site-specific assessments. Ipata Market in Ilorin, for example, serves both Kwara State and neighbouring North Central regions and has not been extensively studied for metal contamination despite its prominence in the automobile trade.

Given the paucity of local data and the environmental and public health risks of unregulated automotive part handling, this study seeks to assess the concentration of selected heavy metals—particularly Pb, Cd, Cr, Ni, and Zn—in commonly used automobile parts sold in Ipata Market, Ilorin. By doing so, it aims to establish a baseline for environmental monitoring, identify potential health risks, and contribute to evidence-based policymaking.

The study employs analytical methods validated by recent environmental chemistry literature and aligns with global efforts to improve sustainability in the vehicle lifecycle. Furthermore, the project bridges the gap between environmental science and public health, providing valuable insights for local stakeholders, including market operators, environmental agencies, and policymakers.

1.2 STATEMENT OF THE PROBLEM

The increasing reliance on used automobile parts in urban markets such as Ipata, Ilorin, has led to a proliferation of informal practices surrounding vehicle dismantling, repair, and resale. While these practices contribute significantly to local economies and provide employment opportunities, they are often unregulated and environmentally precarious. One under-researched dimension of this issue is the potential release and accumulation of heavy metals from these parts into the immediate environment and, by extension, the human population in contact with them.

In Nigeria, attention to heavy metal contamination is generally concentrated on mining regions, industrial effluents, and agricultural soils. However, vehicle parts—particularly brake pads, batteries, radiators, and engine blocks—are known globally to contain significant quantities of hazardous metals such as lead (Pb), cadmium (Cd), chromium (Cr), and nickel (Ni), which may leach into the environment during routine mechanical activities (Iwegbue et al., 2019; Manasfi et al., 2021). The absence of effective environmental regulations in markets such as Ipata raises serious concerns about prolonged human and ecological exposure to these contaminants.

Moreover, there is a distinct lack of baseline data regarding the specific types and concentrations of heavy metals in commonly handled automobile components in Ilorin. This knowledge gap makes it difficult to formulate localised risk assessments or inform

occupational safety guidelines for mechanics, traders, and residents in and around the market.

Given the widespread handling of these parts without protective gear, frequent soil contact, and exposure to residual fluids, the possibility of chronic, low-dose exposure among the population is high. This scenario poses long-term implications for public health, especially in a region where medical surveillance for heavy metal toxicity is minimal. Thus, the problem is not only environmental but also epidemiological and regulatory.

In this context, a scientific assessment of heavy metals in automobile parts at Ipata Market becomes imperative to bridge the gap between informal automotive practices and the hidden environmental health risks they may harbour.

1.3.1 RESEARCH AIM

To assess the concentration and distribution of selected heavy metals in commonly used automobile parts sold in Ipata Market, Ilorin, with a view to evaluating potential environmental and public health risks.

1.3.2 RESEARCH OBJECTIVES

i. To determine the levels of heavy metals (Pb, Cd, Cr, Co, As) in selected automobile parts commonly sold in Ipata Market. ii. Evaluate non-carcinogenic and carcinogenic health risks.

ii. To evaluate the potential environmental and health implications of the detected heavy metals within the context of the Ipata Market environment.

1.4 RESEARCH QUESTION

What are the levels and implications of heavy metal concentrations in selected automobile parts sold at Ipata Market, Ilorin?

1.5 JUSTIFICATION OF THE STUDY

This research is both timely and necessary, given the growing informal economy surrounding automobile maintenance and part resales in Nigeria. While global studies have identified vehicle components as major contributors to urban heavy metal pollution (Lyu et al., 2022; Alghamdi et al., 2021), there remains a significant knowledge gap concerning how this manifests in local contexts such as Ipata Market. This study focuses on specific parts—based on their usage and recyclability—ensures the data generated are directly relevant to public health and environmental management in Ilorin.

Furthermore, the research question addresses an urgent need for evidence-based responses to the invisible yet escalating problem of heavy metal exposure. This is especially crucial in areas like Ipata, where public awareness and protective regulations are minimal, but daily exposure to potentially toxic metals is routine.

Ultimately, the study is worth undertaking because it contributes to the global discourse on environmental pollution from anthropogenic sources, while providing localised data

critical for policy formulation, environmental health advocacy, and future remediation efforts. It lays the groundwork for environmental monitoring in informal automotive markets and could inform sustainable practices in Nigeria's urban centres.

CHAPTER TWO

LITERATURE REVIEW

2.1 LITERATURE REVIEW

This chapter critically examines the existing literature on heavy metal contamination, with particular emphasis on its occurrence in automobile parts. Given the study's focus on Ipata Market, Ilorin, the literature review aims to situate the research within the broader discourse of environmental pollution from anthropogenic sources, notably those arising from informal vehicular dismantling and part reuse.

The purpose of the literature review is to identify, synthesise, and critically assess peerreviewed studies that address the sources, environmental impacts, health implications, and detection methods of heavy metals in vehicle components. This enables a grounded understanding of current knowledge, theoretical frameworks, and methodological approaches relevant to the study.

The structure of the chapter is thematic. It begins with the conceptualisation of heavy metals, followed by a discussion of their environmental sources—both natural and anthropogenic. Subsequently, it explores specific studies on heavy metals in automobile parts, their release mechanisms, and comparisons across geographical contexts. This chapter concludes by highlighting the empirical and theoretical gaps the current study

seeks to address, thereby establishing a rationale for the research conducted in Ilorin, Nigeria.

2.2 CONCEPTUALISING HEAVY METALS

Heavy metals are a loosely defined group of elements characterised by relatively high atomic mass and density—typically above 5 g/cm³—and known for their potential to be toxic or ecotoxic at low concentrations (Heidari et al., 2021). While there is no universally agreed definition, the term often encompasses both essential and non-essential trace elements found in environmental matrices such as soil, air, and water. Common heavy metals of concern include lead (Pb), cadmium (Cd), mercury (Hg), chromium (Cr), arsenic (As), zinc (Zn), copper (Cu), and nickel (Ni).

The classification of heavy metals can be broadly divided into essential and non-essential categories. Essential metals—such as zinc, copper, and iron—are required in trace amounts for biological processes but become harmful when their concentrations exceed physiological limits (Islam et al., 2018). Non-essential metals, such as cadmium, lead, and mercury, have no known biological function and tend to be highly toxic even at low exposure levels (IARC, 2020).

Heavy metals exhibit unique toxicokinetic behaviour due to their chemical persistence and inability to degrade biologically. Once released into the environment, these metals may undergo various transformation processes—such as oxidation, methylation, or

complexation—that affect their mobility and bioavailability. Upon exposure, heavy metals enter the human body through several pathways: inhalation (breathing airborne particles or fumes), ingestion (e.g., via contaminated food, soil, or water), and dermal absorption (particularly in occupational settings).

Inhalation is considered a major route of exposure in environments contaminated by particulate emissions, such as auto-mechanic workshops and urban roadways (ObengGyasi, 2019). For instance, brake pad wear generates airborne particles rich in Cu, Pb, and Zn, which can be inhaled by nearby workers and pedestrians. Ingestion is a concern in areas where soil contamination is prevalent, especially among children engaging in hand-tomouth behaviours. Dermal contact, though generally a less efficient route, becomes significant in occupational scenarios involving unprotected handling of greasy or metallic automotive parts.

Critically, the health impacts of these metals are influenced not only by their concentration but also by their chemical speciation, exposure frequency, and the vulnerability of the exposed population (Heidari et al., 2021). Chronic low-dose exposure is particularly problematic as symptoms may not be immediate but can lead to long-term neurological, renal, or immunological damage. This underscores the importance of monitoring heavy metals in environments where human-metal interactions are routine yet poorly regulated, such as automobile markets and informal workshops.

2.3 SOURCES OF HEAVY METALS IN THE ENVIRONMENT

Heavy metals in the environment originate from both natural and anthropogenic sources. Understanding the relative contribution of these sources is essential to environmental risk assessment, particularly in urban industrial zones where metal pollutants often accumulate in soil and air. These elements when introduced into the environment by activities like the one taking place at Ipata Oloje automobile spare part and recycling market, usually find their way into human bodies to an extent via ingestion of soil (dust) particles, through food chain, drinking of contaminated water and dermal contact. Some of these HMs are vital to human life as sources of minerals and vitamins, and/or play irreplaceable physiological roles in the human body but become toxic at higher concentration and can therefore result to poisoning at relatively high concentrations. This poisoning may result from inhaling air of high concentration near emission sources, drinking-water contamination, or ingestion via food chain. The terrible thing about these heavy metals in the human body is that they tend to bio-accumulate. If these HMs accrue in the tissues faster than the body's detoxification rate, there would be a gradual build-up of these toxins. Bioaccumulation is the gradual build-up of chemicals in living organisms with respect to the chemical's concentration in the environment over time. Any time compounds are ingested, stockpiled quicker than they are used up or excreted, these compounds end up being accumulated in the body (Orosun *et al.,* 2020)

Natural sources of heavy metals include geological weathering of metal-rich rocks, volcanic eruptions, and forest fires. These processes release metals such as Fe, Mn, Cu, and Zn into the environment through erosion or atmospheric transport. For example, volcanic eruptions emit mercury and arsenic into the atmosphere, while soil weathering can contribute to background concentrations of nickel and chromium (Islam et al., 2018).

However, such natural contributions are typically slow and occur over geological timescales, rarely accounting for the elevated concentrations observed in urban areas.

By contrast, anthropogenic sources have a more immediate and concentrated impact. These include:

Industrial emissions: Heavy metals are emitted from manufacturing facilities, especially those involved in metal processing, cement production, and waste incineration. Airborne particulates from such operations often contain lead, cadmium, and chromium, which settle on nearby surfaces and enter local ecosystems (Manasfi et al., 2021).

Mining activities: The extraction and refining of metals generate tailings and runoff containing high concentrations of Pb, Cd, and As. In countries such as Nigeria and Ghana, artisanal mining activities are notorious for contributing to localised contamination and adverse health effects (Doyi et al., 2021).

Urban vehicular emissions: Motor vehicles contribute to heavy metal pollution through exhaust fumes, tyre wear, brake pad abrasion, and leakage of fluids such as lubricants and coolants. Although leaded petrol has been phased out in many countries, including Nigeria, residual lead persists in soils near high-traffic areas (Akinola et al., 2023). Brake wear and tyre degradation continue to emit zinc, copper, and lead into the environment.

Waste from automobile repair and dismantling: This is especially relevant in informal settings such as Ipata Market. Used automobile parts such as batteries, brake pads, and radiators contain significant metal content. During repair or dismantling, these parts may release metal shavings, dust, or oily residues into the environment, contaminating surrounding soil and posing risks to handlers and residents. For example, Iwegbue et al. (2019) reported elevated concentrations of Pb and Cu in areas surrounding auto-mechanic shops in Nigeria.

Case studies from across the globe provide concrete evidence of these anthropogenic impacts. In China, Lyu et al. (2022) demonstrated that brake and tyre wear accounted for up to 40% of urban airborne particulate metal concentrations. In South Africa, Mngomezulu and Monyai (2019) found hazardous levels of Cd and Pb in soil samples collected from informal vehicle dismantling sites. In Ghana, Doyi et al. (2021) noted that automobile workshops were hotspots for Pb and Cr accumulation in urban soils.

These findings are consistent with research conducted in Nigeria. Olatunji et al. (2022) examined soils in auto-mechanic clusters in Ibadan and found Pb levels far exceeding

WHO and FAO permissible limits. Similarly, Akinola et al. (2023) reported dangerous accumulations of Ni and Cr in roadside dust in Kano. These studies confirm that informal automobile-related activities—particularly in unpaved, crowded environments—are major contributors to heavy metal pollution.

The critical issue is that unlike industries or mines, informal markets are rarely subject to environmental regulations, monitoring, or remediation. The widespread handling of toxic materials without adequate protective equipment further compounds human exposure risks.

Thus, assessing and understanding heavy metal sources in such contexts becomes vital for developing interventions tailored to urban environmental realities in Nigeria and beyond.

2.4 HEAVY METALS IN AUTOMOBILE COMPONENTS

Automobile parts are complex assemblies of metal alloys, polymers, and composite materials, many of which contain trace and sometimes substantial quantities of heavy metals. These materials serve critical mechanical and electrical functions but also represent potential sources of environmental and occupational contamination when poorly managed or disposed of.

Brake pads are among the most recognised contributors to heavy metal emissions from vehicles. They are manufactured using metal-containing binders, abrasives, and

lubricants. Studies by Adusei et al. (2020) and Lyu et al. (2022) have identified significant concentrations of copper (Cu), lead (Pb), and zinc (Zn) in brake pad dust. When frictional wear occurs during braking, these metals are released as fine airborne particles that may settle in roadside dust or be inhaled by nearby individuals.

Batteries, particularly lead-acid types used in older vehicles, contain high concentrations of lead and cadmium. Improper storage, dismantling, or disposal of batteries—as often observed in markets like Ipata—can result in acid spills and heavy metal leakage. Mngomezulu and Monyai (2019) observed dangerously elevated Pb levels in soil samples taken from South African battery dismantling sites. In Nigeria, battery-related Pb pollution has been linked to localised soil and water contamination (Iwegbue et al., 2019).

Radiators and cooling systems often utilise metal alloys containing chromium (Cr), nickel (Ni), and zinc to enhance heat resistance and corrosion control. Over time, these metals may leach into cooling fluids or be released during maintenance and scrapping activities. Alghamdi et al. (2021) reported that used radiator fluids contained detectable levels of heavy metals that could contaminate soil when spilled.

Engine blocks and associated components are commonly composed of cast iron and steel alloys, often infused with nickel, chromium, or molybdenum for durability. While generally stable during use, these components release metal particulates during grinding,

cutting, or disassembly. Waste oils and greases used in engines are also vectors for metal contamination, particularly in unregulated disposal scenarios.

The mechanisms of metal release from these parts include mechanical wear (e.g., braking), thermal stress (e.g., engine heat), chemical degradation (e.g., battery corrosion), and physical dismantling. In informal markets, these processes often occur on bare soil or concrete surfaces without containment measures, facilitating the transfer of metals into the surrounding environment.

Comparative studies highlight distinct regional differences. In high-income countries, regulations such as the EU Restriction of Hazardous Substances (RoHS) directive limit the permissible metal content in vehicle components. Consequently, brake pads and batteries in Europe tend to contain lower concentrations of Pb and Cd (Manasfi et al., 2021). By contrast, in low- and middle-income countries (LMICs), including Nigeria, imported second-hand parts are rarely subjected to environmental screening or control. Many of these parts originate from decommissioned vehicles abroad, raising concerns about transboundary waste dumping (Ochieng et al., 2020).

In Nigeria, studies by Akinola et al. (2023) and Olatunji et al. (2022) confirm that automechanic areas are saturated with metal-rich dust and soils, pointing directly to automobile components as a primary source. However, despite growing concern, there remains a lack of data on which parts contribute most significantly to contamination in

specific markets. This highlights the need for targeted studies—such as the present one in Ipata Market—to identify high-risk components and inform future regulation.

2.5 HEALTH AND ENVIRONMENTAL EFFECTS OF KEY HEAVY METALS

Heavy metals pose significant health and environmental threats due to their bioaccumulative nature, persistence in the environment, and toxicity even at low concentrations. This section explores the toxicological and ecological consequences of the major metals typically found in automobile components.

Lead (Pb) is a well-known neurotoxin. Chronic exposure can result in cognitive dysfunction, developmental delays in children, and damage to the renal and cardiovascular systems. According to the International Agency for Research on Cancer (IARC), lead and its compounds are classified as probable human carcinogens (Group 2A) (IARC, 2020). The WHO (2021) reports that no safe level of lead exposure has been identified, with neurodevelopmental toxicity especially concerning in children. In dismantling and autorepair environments, lead is released from batteries, solder, and painted components, contaminating soil and inhalable dust (Gupta et al., 2020).

Cadmium (Cd) is another hazardous metal prevalent in vehicle batteries and brake systems. The IARC (2019) classifies cadmium and cadmium compounds as carcinogenic to humans (Group 1), associated with prostate and lung cancers. Chronic cadmium exposure primarily affects the kidneys and liver and may cause bone demineralisation.

Soil contaminated with cadmium from auto waste can leach into crops, posing food chain risks (Yabe et al., 2021).

Chromium (Cr), particularly hexavalent chromium (Cr^{6+}), is used in coatings and engine parts. It causes respiratory tract irritation, skin ulcers, and allergic dermatitis. Cr^{6+} is classified as a Group 1 carcinogen by IARC and is linked to lung cancer in occupationally exposed individuals (IARC, 2018). Soil and water near auto-dismantling sites have shown elevated chromium levels, impairing microbial soil health and affecting groundwater quality (Eze et al., 2022).

Nickel (Ni) is widely used in automotive alloys. Long-term inhalation of nickel dust or fumes can cause respiratory ailments, such as bronchitis and asthma, and is a known skin sensitiser (WHO, 2020). The IARC classifies certain nickel compounds as carcinogenic (Group 1), especially in the context of occupational exposure (IARC, 2020).

Zinc (Zn), though essential in trace amounts, can be harmful at elevated levels. Automobile tyres and oils are major sources. Excess zinc in the environment leads to phytotoxicity and alters soil microbial activity, reducing crop productivity. In humans, excessive ingestion can cause gastrointestinal irritation and disrupt copper metabolism (Liang et al., 2019).

Environmental contamination from these metals affects terrestrial and aquatic systems. Soils around automobile repair hubs have shown reduced fertility due to heavy metal

accumulation, leading to bioaccumulation in plants and contamination of the food chain (Bortey-Sam et al., 2020). Leaching of metals into groundwater poses additional public health risks, particularly in peri-urban areas with informal dismantling operations.

Understanding these effects underscores the need for proper environmental and occupational safety protocols in markets such as IPATA, where informal automobile part trade and dismantling are prevalent.

2.6 ANALYTICAL TECHNIQUES FOR DETECTING HEAVY METALS IN SOLIDS

Accurate determination of heavy metal concentrations in automobile parts and contaminated solids requires robust analytical techniques. This section discusses widely used methodologies for assessing heavy metals, especially in solid waste and metallic residues.

Sample Collection and Preparation

Effective analysis begins with representative sampling and appropriate preparation. Samples are usually dried, ground, and digested using acid mixtures (commonly HNO_3 or aqua regia) to extract metal ions for analysis. This pre-treatment ensures homogeneity and consistent analytical outcomes (Okoro et al., 2021).

Atomic Absorption Spectroscopy (AAS)

AAS remains a gold-standard method for quantifying heavy metals in environmental samples due to its specificity, low detection limits, and cost-effectiveness. It is particularly suited to low-resource settings. However, it requires meticulous calibration and can only analyse one element at a time (Yakubu et al., 2020).

Inductively Coupled Plasma Mass Spectrometry (ICP-MS)

ICP-MS offers ultra-trace detection levels and multi-element analysis, making it ideal for complex matrices such as alloy fragments and soil. Its high sensitivity and broad dynamic range make it widely used in academic and industrial laboratories. However, the high operational and maintenance costs limit its applicability in developing countries (Tang et al., 2019).

X-Ray Fluorescence (XRF)

XRF is a non-destructive, rapid method that requires minimal sample preparation. It is particularly effective for solid metallic samples and is increasingly adopted for field screening. Although less sensitive than ICP-MS, portable XRF devices enable on-site analysis of automobile components and contaminated soils (Ezeonu et al., 2022).

In contexts like IPATA Market, combining XRF and AAS allows preliminary field assessment followed by confirmatory laboratory analysis. Nonetheless, local capacity

limitations—such as inadequate infrastructure, lack of skilled personnel, and equipment maintenance—pose barriers to widespread deployment.

Continued development of portable, low-cost detection tools remains crucial for enhancing environmental monitoring in auto-related industries in Nigeria and other low- and middleincome countries (LMICs).

2.7 GLOBAL PERSPECTIVES ON AUTOMOBILE-DERIVED METAL POLLUTION

The environmental burden of automobile-derived heavy metals is a global concern, particularly in urban centres with large vehicle populations and auto-repair clusters. Crosscountry studies reveal varied contamination levels shaped by regulatory, economic, and technological contexts.

In Asia, industrialised and developing nations alike contend with heavy metal emissions from vehicular sources. In India, Mishra et al. (2021) reported high concentrations of lead, cadmium, and chromium in soils near informal auto-repair yards in Delhi, often exceeding WHO limits. Similarly, studies from China's urban centres indicate that heavy metals in roadside soils are strongly correlated with vehicular traffic and unregulated dismantling (Zhao et al., 2019). South Korea has implemented stringent pollution control measures, but localised hotspots remain near industrial vehicle centres (Park et al., 2020).

In Europe and North America, strong environmental regulations, including the EU Restriction of Hazardous Substances Directive (RoHS) and US EPA standards, have curbed emissions of toxic metals. For instance, brake pad manufacturers in the US have reduced copper content through the Better Brakes Rule, mitigating runoff contamination (US EPA, 2021). Nevertheless, urban areas with legacy contamination, such as Detroit, still report elevated soil lead levels due to historical vehicular emissions (White et al., 2020).

In contrast, Africa's rapid urbanisation and weak environmental oversight have exacerbated the problem. Studies in Ghana (Bortey-Sam et al., 2020) and Kenya (Odhiambo et al., 2018) have shown that auto-mechanic clusters are significant contributors to soil and air heavy metal pollution. Waste oils, metal scraps, and battery residues are often discarded improperly, contaminating soil, water, and air.

In Nigeria, markets such as Ladipo in Lagos and IPATA in Ilorin serve as major automotive hubs with informal dismantling and reassembly activities. Eze et al. (2022) observed that heavy metals including Pb, Cd, and Zn were present in alarming concentrations in soil samples from auto-repair sites in Enugu. The lack of occupational health protocols and environmental protection policies enables continued degradation.

Comparative studies underscore the role of regulatory frameworks and technological adoption in reducing automotive-derived metal pollution. Countries with strong

enforcement mechanisms and public awareness have achieved measurable success in pollution reduction, while developing nations still face escalating risks.

Understanding this global disparity is critical for informing localised solutions tailored to the socio-economic and infrastructural realities of environments like IPATA Market.

2.8 NIGERIA-SPECIFIC STUDIES AND RESEARCH GAPS

Studies on heavy metal contamination in Nigeria have primarily centred on urban centres such as Lagos, Ibadan, Kano, and Aba, with a predominant focus on industrial sites, road dust, auto-mechanic workshops, and electronic waste disposal locations. For instance, Adefehinti et al. (2020) investigated heavy metals in road dust across major traffic corridors in Lagos, reporting elevated levels of Pb, Cd, Zn, and Cu, particularly near mechanic villages. Similarly, Nwachukwu and Umunnakwe (2018) found significant concentrations of Cr and Ni around auto-repair clusters in Aba, where direct discharge of waste materials into the surrounding environment is common. These studies have raised alarms over the environmental and human health implications of unregulated vehicular and mechanical
activities.

In Ibadan, research by Oyeyiola et al. (2019) analysed soils around battery repair workshops, finding alarming levels of Pb and Cd above WHO and FEPA (Federal Environmental Protection Agency) permissible limits. In Kano, Mohammed et al. (2021)

assessed heavy metal contamination in urban soil and observed correlations between high traffic density, informal vehicle maintenance practices, and metal accumulation in adjacent soils and drains. These findings provide strong evidence that auto-related activities in Nigerian cities contribute significantly to heavy metal loadings in the terrestrial environment.

However, most of these studies are limited to large-scale urban environments or highly industrialised cities. They often overlook market environments such as Ipata Market in Ilorin, where automobile dismantling, repairs, spare parts trading, and metal reuse are rampant yet largely unregulated. The informal economy in such spaces remains understudied despite its significant footprint on the local environment. Additionally, prior research in Nigeria often treats "automobile waste" in a generalised fashion, with insufficient attention to the differential heavy metal composition of specific car parts such as brake pads, batteries, or radiators.

Furthermore, while some studies have evaluated the environmental dimension of pollution, few have adequately linked heavy metal data to potential human exposure pathways— particularly among market workers, traders, and local residents. Ilorin and the broader North Central zone of Nigeria are notably underrepresented in this domain. The absence of baseline data from these areas constrains public health planning, risk assessments, and environmental regulation enforcement.

Therefore, this study addresses a critical research gap by focusing specifically on automobile parts as a source of heavy metals in a bustling market environment in Ilorin. By analysing discrete part types for specific metal pollutants, the study seeks to generate granular data that can inform local health risk interventions, policy frameworks, and environmental management plans.

2.9 THEORETICAL AND EMPIRICAL GAPS

Despite the growing literature on heavy metal contamination in urban Nigeria, notable theoretical and empirical gaps remain. Theoretically, most studies have failed to integrate comprehensive pollution pathway models that explain the link between the contamination source, transmission medium, and exposed population. Many investigations rely on point sampling or area-based measurements without embedding these within a conceptual framework that could predict or explain patterns of exposure and accumulation.

Empirically, one of the most critical gaps lies in the lack of specificity regarding the types of automobile parts studied. Studies often refer to "automobile waste" or "mechanic sites" generically, with little breakdown of the different components, each of which may have distinct metal profiles and release mechanisms. For instance, brake pads typically contain copper, zinc, and lead, whereas batteries are more likely to leach cadmium and lead. The absence of such disaggregated data limits the potential for tailored intervention or substitution of hazardous components.

Moreover, very few studies conduct full environmental health risk assessments linked to heavy metal presence in automobile components. Although some research acknowledges the presence of heavy metals, it seldom quantifies the potential human exposure through ingestion (e.g., hand-to-mouth contact), inhalation (e.g., of fine particles), or dermal pathways. This omission is significant given that traders, technicians, and customers in informal markets like Ipata are likely to have prolonged and repeated contact with contaminated surfaces and air.

Another pressing empirical gap is the lack of regulatory benchmarks and monitoring practices for informal market environments. The majority of Nigerian environmental regulations are either outdated or poorly enforced, especially in areas outside the purview of industrial pollution control. While FEPA and NESREA provide general environmental quality standards, these are not sufficiently adapted to the realities of informal economic hubs, where materials are dismantled, reused, and resold without adequate safety oversight.

This study aims to bridge these theoretical and empirical gaps by adopting a conceptual pollution pathway framework and conducting component-specific assessments. It further addresses the need for locally relevant data that can inform public health guidelines and environmental risk communication in Ilorin and similar contexts.

CHAPTER THREE

METHODOLOGY

3.1 STUDY AREA: IPATA OLOJE MARKET, ILORIN

Ipata Oloje Market is located in Ilorin West Local Government Area of Kwara State, Nigeria. It is a well-known hub for automobile parts—both new and second-hand attracting traders and consumers from across North Central Nigeria. The market features dense clusters of open-air stalls, workshops, and dismantling sites where vehicles are stripped for resale or reuse. Informal handling, disposal, and repurposing practices dominate the market environment.

The geographical coordinates of Ipata-Oloje Market are approximately Latitude 8.5080° N and Longitude 4.5366 ° E (Google Earth, 2024). The location was purposefully chosen for several compelling reasons. First, the market's environmental relevance arises from its commercial density, which indicates a high volume of potential contaminants. Second, its proximity to surrounding residential neighborhoods raises serious concerns regarding public health, as nearby residents and traders could be exposed to hazardous materials, particularly heavy metals that can leach into local water supplies.

Research surrounding the impact of informal automotive practices on urban environmental health is extensive. Studies have emphasized the role of markets like Ipata-Oloje in exacerbating urban contamination. Akinola et al. (2021) and Olayinka &

Alo (2018) have investigated similar locales and noted the perilous effects of hazardous waste on local ecosystems. Given these precedents, the Ipata-Oloje market stands out as a significant case study for assessing potential environmental and health risks from contaminated water sources.

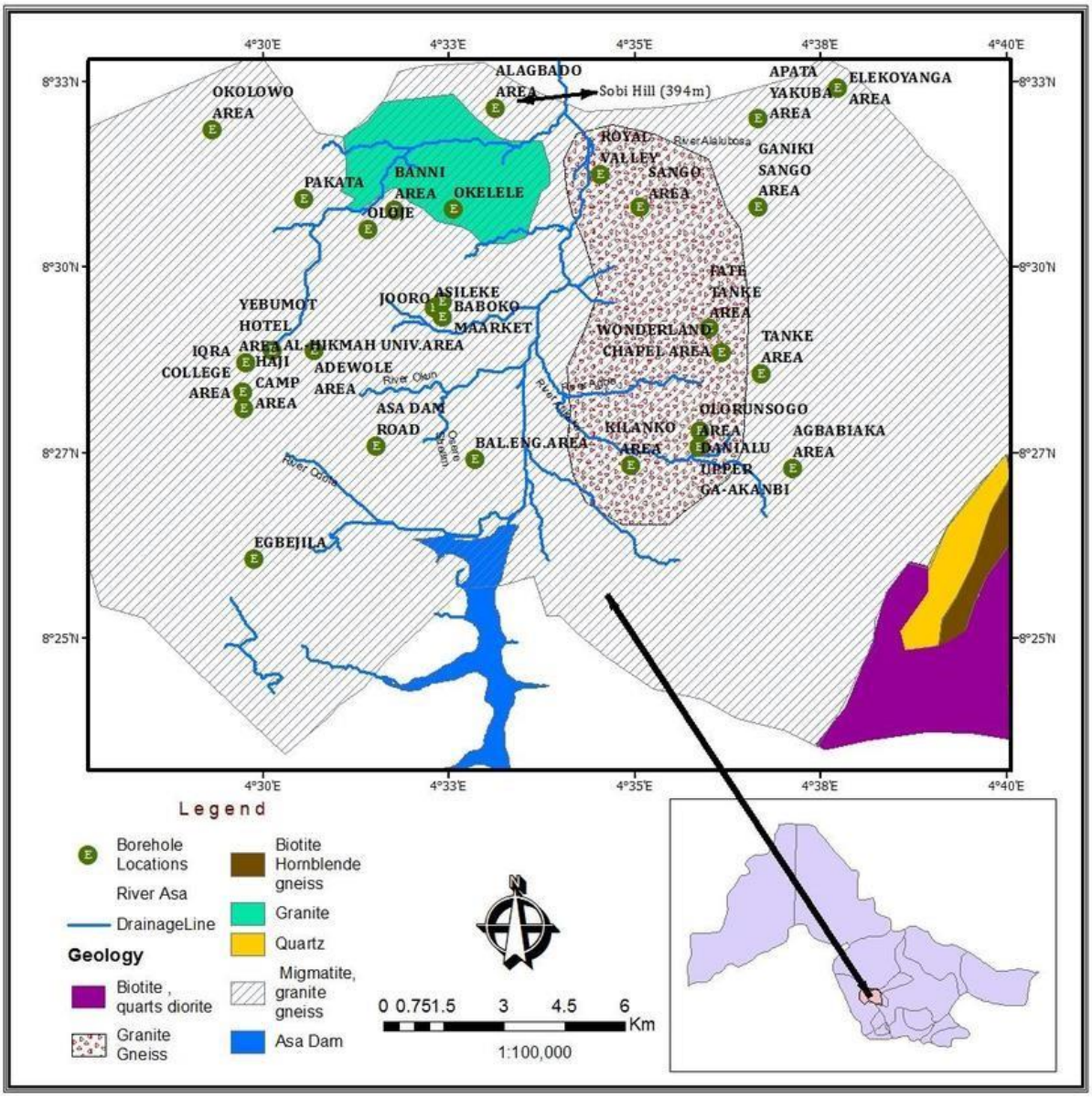

Fig. 1: Map showing the study area; Ipata Oloje

3.2 SAMPLE COLLECTION

3.2.1 WATER SAMPLE COLLECTION AND PREPARATION

Water samples were methodically collected from several locations within the market to ensure comprehensive data collection:

- Open Wells: Often used by local traders for daily activities, these wells can be highly susceptible to contamination from nearby mechanical activities.

- Borehole: In addition to open wells, samples were taken from boreholes, as they serve as an important source of water for many residents and traders in the vicinity, thereby influencing their exposure to contaminants.

Sampling Procedure

A systematic approach was taken to collect water samples, with a focus on maintaining integrity and ensuring reliability of results:

- Sample Containers: Samples were collected using pre-washed, sterilized 1-liter plastic bottles to eliminate any potential for contamination.

- Time of Collection: Samples were collected early in the morning, strategically selected to avoid diurnal variations that could affect water quality measurements.

- Acidification: Immediately after collection, samples were acidified with nitric acid (HNO_3) to stabilize the metal content and prevent precipitation, ensuring a more accurate analysis.

- Storage: Each sample was labeled and placed in a cooler box to maintain temperature consistency before undergoing laboratory analysis.

Sample Preparation

To accurately determine the concentration of PTMs in the collected water samples, a thorough sample preparation process was employed. Water samples underwent digestion utilizing the aqua regia method, formulated in a 3:1 ratio ($HCl:HNO_3$). This ratio is particularly suited for the oxidation of metals, enhancing the recovery of a wide range of elements.

- Digestion Procedure: A 100 ml aliquot of the water sample was measured into a clean 250 ml digestion flask. Subsequently, 15 ml of concentrated nitric acid and 5 ml of concentrated hydrochloric acid were added to the flask.

- Heating Process: The sample was subjected to controlled heating on a hot plate for approximately 15 minutes, ensuring that evaporation reduced the volume to less than 50 ml. Care was taken to prevent drying out, with special attention given to the bottomof the flask to avoid residue.

- Cooling and Filtration: Once the digestion was complete, the flask was allowed to cool to room temperature. The cooled mixture was then filtered through Whatman No. 1 filter paper into 50 ml standard plastic vials, ensuring thorough rinsing with distilled water to maximize sample recovery. A few milliliters of distilled water were added and the mixture was filtered into a 25 ml standard flask and it was transferred into a plastic reagent bottle for Atomic Absorption Spectrometry (AAS). The Atomic Absorption Spectrometry was carried out at University of Ilorin central research laboratory using Buck Scientific Model 210 VGP Atomic Absorption Spectrophotometer.

3.2.2 SOIL SAMPLE COLLECTION AND PREPARATION

A total of twelve (12) sediment samples were collected from the market. The sediment samples were collected using a soil auger and put in black nylon bags about 2kg each. These samples were sent to the laboratory where they were screened to remove macroscopic traces of stones, glass, rubber, hair, animal, and plant matter to ensure that the materials to be analyzed are free from such contaminants. The samples were air-dried at room temperature in the Laboratory for some days to reduce the mass contribution of water and to avoid any chemical reaction (Kanu, *et al.,* 2013). The samples were ground using an agate mortar and sieved through a 1 mm sieve mesh and stored in well-labeled plastic containers for digestion. Aqua Regia Method was employed for the digestion of trace metals in soil samples. 1g of each sample (soil) was

weighed into a clean digestion flask and 9 ml of concentrated HNO_3, 3 ml of concentrated HCl were added into the sample in the digestion flask (USEPA, 1986). The whole samples were heated in a hot plate until all the brownish fumes expelled out (Nitrogenous Compound), which confirm that the sample is digested and the samples were allowed to cool at room temperature and a few milliliters of distilled water added, and the mixture was filtered into 25 ml standard flask which was transferred into plastic reagent bottle for Atomic Absorption Spectrometry (AAS) for the quantitative determination of chemical elements. The technique measures the concentrations of elements in digested samples down to parts per billion of a gram (µg dm^{-3}) in a sample. The Atomic Absorption Spectrometry was carried out at University of Ilorin central research laboratory using Buck Scientific Model
210 VGP Atomic Absorption Spectrophotometer.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 RESULTS

The summary of the results of the spectrometry analysis for the concentration of Heavy Metals present in the samples collected from the locations were presented in Table 2.

Table 4.0. Statistical summary of heavy metal concentration of water samples in Ipata Oloje.

Elements	Min	Max	Mean	Median	Stdev	Coefficient of Variation
Pb	0.021	0.25	0.139	0.15	0.0878	63.16546763
Cd	0.002	0.0188	0.0089	0.01	0.0058	65.16853933
Cr	0.01	0.25	0.0788	0.045	0.07255	92.06852792
Co	0.24	0.83	0.594	0.645	0.1978	33.2996633
As	0.001	0.023	0.0103	0.0112	0.007	67.96116505

Table 4.1 Statistical summary of heavy metal concentration of sediments samples collected in Ipata Oloje.

Elements	Min	Max	Mean	Median	Stdev	Coeficent Of Variation
Pb	0.78	7.2	3.872	3.915	2.003076	51.73233746
Cd	0.16	1.61	0.942	0.98	0.387064	41.08962539
Cr	0.81	3.11	1.782	2.03	0.663879	37.25471761
Co	0.68	5.43	2.084	1.235	1.531466	73.48686442
As	0.22	1.51	1.055	1.14	0.36598	34.69008705

4.2 ASSESSMENT OF HEAVY METAL HEALTH RISK IMPACT

4.2.1 NON-CARCINOGENIC

This research applies to the Health Risk Model developed by the US Environmental Protection Agency (US-EPA) to assess human exposure to heavy metals. Human health risks from the consumption of the herbal drink sample were evaluated via the ingestion route based on the equation provided by the United States Environmental Protection Agency (Olayinka *et al.,* 2016). To quantify exposure levels, the Average Daily Intake (ADI) was calculated for ingestion route, using equations from Li *et al.* (2014). This approach enables the estimation of human exposure to heavy metals from various sources.

$$ADI_{ingestion} = \frac{C_{ij} \times IngR_j \times EF \times ED \times 10^{-6}}{BW \times AT} \quad (1)$$

where C_{ij} is the concentration of heavy metal i in medium j, $IngR_j$ is the in ingestion rate of j medium particles (mg/day or L/day), $InhR_j$ is the ingestion rate of j medium particles (m^3/day), $IngR_j$ is the inhalation rate of j medium particles (mg/day or L/day), PEF is the particle emission factor (m^3/kg), EF is the exposure frequency (day/year), EF is the Exposure Time, KP is the Permeability Constant, ED is the lifetime exposure duration (year), BW is the body weight of the exposed individual, AT

is the time period over which the dose is averaged (day), SA is the exposed skin surface area (cm^2), AF is the

adherence factor (mg/cm^2-day), $ADI_{ingestion}$, $ADI_{inhalation}$, ADI_{dermal} are the average daily intake due to ingestion, inhalation, and dermal respectively (mg/kg-day), and ABF is the dermal absorption factor (unitless).

The non-carcinogenic risk value, represented by Target Hazard Quotient (HQ) is calculated as the ratio of daily intake (CDI) to the reference dose (RfD), was determined for each heavy metal using Equations 2.

$$HQ_i = \frac{CDI^i}{RfD_i} \qquad (2)$$

CDI represents the average daily intake of a specific toxic element i, and RfD is the chronic reference dose for the same element measured in (mg/kg-day) (Muhammadi, 2020; USEPA, 2001). If the Hazard Quotient (HQ > 1) exceeds 1, there is a high probability of adverse health effects for the exposed inhabitants i.e. the existence of carcinogenic is believed to occur. Conversely, if (HQ < 1) is less than unity, there is no probability of adverse health effects, hence it is the accepted as there is no carcinogenic risk (Jaffar *et al.,* 2017; Mohammadi *et al.,* 2019; Ogarekpe *et al.,* 2023). ADI_{dermal} are the average daily intake due to ingestion, inhalation, and dermal respectively (mg/kgday), and ABF is the dermal absorption factor (unitless).

Results of the doses obtained for each element and pathway were further divided by the toxicity threshold value also known as the reference dose (RfD, mg/kg-day) to obtain a non-carcinogenic hazard quotient (HQ) as shown in Eq. (4). Meanwhile, the carcinogenic risk, which is used to access the probability of an individual developing any type of cancer due to exposure to cancer-causing agents during a lifetime (Li *et al.,* 2014), was evaluated by multiplying the doses in each pathway by the corresponding slope factor (SF, per mg/kg-day) as in Eq. (4). The hazard index approach was then employed to calculate the overall potential for non-carcinogenic effects by all exposure pathways as in Eq. 3

$$HQ_i = \frac{ADI_i}{RfD_i} \quad (3)$$

$$Carcinogenic\ Risk = ADI_i \times SF_i \quad (4)$$

$$HI = \sum HQ_i$$

The acceptable value of HI is ≤ 1.0. For HI ≥ 1.0, the non-carcinogenic risk is probable and the risk increases with an increase in HI. However, carcinogenic risk values fall in the range of 1×10^{-4} and 1×10^{-6}. In which values greater than 1×10^{-4} are terms "unacceptable" and values less than 1×10^{-6} are considered not to pose any significant cancer risk.

4.2.2 THE CARCINOGENIC RISK ASSESSMENT

Carcinogenic risk represents the chance or probability of developing cancer throughout an individual's lifetime due to exposure to carcinogenic hazards. To assess carcinogenic risk, Equation 5 was used:

$$ILCR = CDI_i \times SF_i \quad (5)$$

Where ILCR is the Incremental Lifetime Cancer Risk, CDIi and SFi are the Chronic Daily Intake and the Cancer Slope Factor of carcinogenicity in (mg/kg per day) respectively. ILCR values below 1×10^{-6} are generally considered safe, posing no discernible cancer risk to humans. On the contrary, values exceeding 1×10^{-4} are largely assumed to be high, indicating a higher cancer risk. Therefore, the acceptable range for the ILCR falls between 1×10^{-4} and 1×10^{-6} (Mohammadi *et al.,* 2020; Ogarekpe *et al.,* 2023; Orosun *et al.,* 2023).

The children population was included in this estimation because they have been sighted to be given these drinks by parents/ guardians in this vicinity and acknowledging this phenomenon appears to be an important part of the investigation (Olayinka *et al.,* 2016).

4.3 STATISTICAL ANALYSIS

The obtained data were statistically analyzed using Microsoft Excel 365 for analysis, graphical presentation, and for computing the toxicological risk assessment.

Table 4.2: Exposure parameters are used in calculating the human health risks (Isinkaye, 2018; Orosun, 2021).

S/N	Factor	Explanation	Adult	Children	S.I Unit
1	IngR	Ingestion Rate	2	1	mg/day for soil and l/day for water
3	EF	Exposure frequency	365	365	day/year
4	ED	Exposure duration	55	6	Years
5	BW	Body mass	70	15	Kg
6	AT	Period of exposure	For Non-Carcinogenic: ED × 365 = 20075, Carcinogenic: 70 × 365	2190	Days
9	AF	Adherence Factor	0.07	0.2	mg/cm^2-day
11	RfD	Chronic Reference Dose: ingestion	Pb (3×10^{-3}), Cd (1×10^{-3}), Zn (0.25),	Null	mg/kg/day
12	SF	Carcinogenic slope factor	Pb (8.5×10^{-3}), Cr (0.5), As (1.5), Cd (0.38)	Null	$(mg/kg/day)^{-1}$

4.3.1 HEAVY METALS DISTRIBUTION IN WATER AND SEDIMENT SAMPLES.

The statistical analysis of heavy metal concentrations is presented in Tables 1 and 2. Results show that both the arithmetic mean and 50th percentile values for Pb, Cd, Cr, Co, and As are generally higher in sediment samples than in water samples. In water, the mean concentration of heavy metals increases in the order: Cd < As < Cr < Pb < Co. For sediment samples, the order is: Cd < As < Cr < Co < Pb. This distribution pattern indicates that the presence of these metals varies across media and is influenced by their concentration levels in each.

When arranged in decreasing order, the distribution remains consistent: Cd < As < Cr < Pb < Co for water, and Cd < As < Cr < Co < Pb for sediments. This suggests that metal accumulation is medium-specific, with certain elements more concentrated in one than the other.

The coefficient of variation (CV) was used to assess the dispersion of metals in the study area (refer to Table 4). All metals demonstrated high variability in water samples, except Cobalt (Co), which showed moderate variability. In sediment samples, only Lead (Pb) and Cobalt (Co) showed high variability, while Cadmium (Cd), Chromium (Cr), and Arsenic (As) exhibited moderate variation.

Table 4.3: Degree of variation and its indication. Karim *et al.,* 2015.
x; coefficient of variation

Degree of Variation	Indication
X<20%	Low variability
20% <X ≤ 50%	Moderate Variability
50% < X ≤ 100%	High Variability
>100%	Exceptionally High Variability

4.3.2 ECOLOGICAL RISK ASSESSMENT

According to Hakanson (1980) the monomial ecological risk factor ($E_f{}^i$) can be categorized as:

$E_f{}^i < 40$ = low potential ecological risk;

$40 \leq E_f{}^i < 80$ = moderate potential ecological risk;

$80 \leq E_f{}^i < 160$ = considerable potential ecological risk;

$160 \leq E_f{}^i < 320$ = high potential ecological risk;

$E_f{}^i \geq 320$ = very high ecological risk at hand for the substance in question.

In the same way, Hakanson also described the potential ecological risk index (R_I), which is the sum of the risk factor as;

$R_I < 150$ = low ecological risk;

$150 \leq R_I < 300$ = moderate ecological risk;

$300 \leq R_I < 600$ = considerable ecological risk.

$R_I \geq 600$ = very high ecological risk at hand for the substance in question.

Observing from Table 4, all sediment samples obtained from the location does not pose a considerable potential ecological risk and at the same time, the sediments constitute an insignificant amount of pollution in the study area.

4.3.3 CARCINOGENIC AND NON-CARCINOGENIC RISK ASSESSMENT OF WATER SAMPLES

Table 5 presents the statistical analysis of Average Daily Intake (ADI) through both ingestion and dermal pathways. The mean ADI via ingestion (ADI_{ing}) ranged from 2.90E10 to 1.70E-08 mg/kg-year, with Cobalt showing the highest intake and Arsenic the lowest. For the dermal pathway (ADI_{derm}), values ranged from 1.02E-13 to 2.84E-11 mg/kg-year, with Chromium contributing the highest intake level among the elements.

The estimated Hazard Index (HI) values for all elements were below one (<1), aligning with the U.S. EPA (2001) threshold, and indicating that non-carcinogenic risks from exposure to these water samples are negligible. Carcinogenic risk assessment (also in Table 5) further revealed that the concentrations of Lead (Pb), Cadmium (Cd), Chromium (Cr), and Arsenic (As) in the water samples pose no significant cancer risk via either ingestion or dermal exposure, as all calculated cancer risk values were below the acceptable limit of 1.0E-06. These findings suggest that the heavy metal concentrations in the water do not present notable health threats under current exposure conditions.

Table 4.4: Human risk estimation for water samples

Heavy Metal	Statistics	concentration	ADI_{ing}(water)	cancer risk Ing	HQ_{ing}	ADI (dermwater)	Hq_{derm}	Cancer Risk Derm	HI
Pb	Min	0.021	6E-10	5.1E-13	1.71E-07	4.17E-13	7.94E-10		1.72E-07
	Max	0.25	7.14E-09	6.07E-11	2.04E-06	4.96E-12	9.45E-09		2.05E-06
	Mean	0.139	3.97E-09	3.37E-11	1.13E-06	2.76E-12	5.26E-09		1.14E-06
Cd	Min	0.002	5.71E-11	2.17E-11	5.71E-08	3.61E-11	3.61E-06		3.67E-06
	Max	0.0188	5.37E-10	2.04E-10	5.37E-07	4.85E-12	4.85E-07		1.02E-06
	Mean	0.0089	2.54E-10	9.65E-11	2.54E-07	2.29E-12	2.29E-07		4.83E-07
Cr	Min	0.01	2.86E-10	1.48E-10	9.53E-08	2.64E-12	4.4E-08		1.39E-07
	Max	0.25	7.14E-09	3.57E-09	2.38E-06	6.61E-11	1.1E-07		2.49E-06
	Mean	0.0788	2.25E-09	1.13E-09	7.5E-07	2.84E-11	4.73E-07		1.22E-06
Co	Min	0.24	6.86E-09		3.43E-07	1.03E-12	6.44E-11		3.43E-07
	Max	0.83	2.37E-08		1.19E-06	3.57E-12	2.23E-10		1.19E-06
	Mean	0.594	1.7E-08		8.5E-07	2.55E-12	1.59E-10		8.5E-07
As	Min	0.001	2.86E-11	4.29E-11	9.53E-08	9.92E-15	8.07E-11	3.63E-08	9.54E-08
	Max	0.023	6.57E-10	9.86E-10	2.19E-11	2.28E-11	1.85E-07	8.34E-05	1.85E-07
	Mean	0.0103	2.94E-10	4.41E-10	9.8E-07	1.02E-13	8.29E-10	3.73E-07	9.81E-07

4.3.4 CARCINOGENIC AND NON-CARCINOGENIC RISK ASSESSMENT OF SOIL SAMPLES

Between the two exposure pathways considered (ingestion and dermal contact), the ingestion route showed higher average daily intake (ADI) values for all elements. The trend observed was As < Cd < Cr < Co < Pb, with Lead (Pb) having the highest ADI (5.5E-06) and Arsenic (As) the lowest (1.51E-06). In contrast, the dermal pathway followed a different trend: Co < Pb < As < Cr < Cd, with Cadmium (Cd) recording the highest ADIderm (7.52E-07) and Cobalt (Co) the lowest (1.19E-08).

Hazard Index (HI) values for all elements in the soil were below or equal to 1.0 (HI≤1), indicating no significant non-carcinogenic health risks, in line with the USEPA (2001) guidelines. Similarly, cancer risk values via the ingestion pathway were below 1.0E-06, suggesting no significant carcinogenic threat. However, in the dermal exposure pathway, Arsenic presented a mean cancer risk value of 6.59E-01, which exceeds the acceptable threshold (1.0E-06–1.0E-04). This finding highlights a substantial carcinogenic risk from dermal contact with Arsenic-contaminated soil in the study area.

Table 4.5: Human risk estimation for soil samples

Heavy Metal	Statistics	Concentration (Soil)	ADI(soil)	cancer risk Ing soil	Hqing	ADI (derm soil)	Hqderm	Cancer Risk Derm water	HI
Pb	Min	0.78	1.11E-06	9.44E-09	3.17E-04	2.67E-08	4.84E-05		3.
	Max	7.2	1.03E-05	8.76E-08	2.94E-03	2.46E-07	4.46E-04		3.
	Mean	3.872	5.53E-06	4.70E-08	1.58E-03	1.32E-07	2.39E-04		1.
Cd	Min	0.16	2.29E-07	8.70E-08	2.29E-04	1.28E-07	1.28E-02		1.
	Max	1.61	2.30E-06	8.74E-07	2.30E-03	1.28E-06	1.28E-01		1.
	Mean	0.942	1.35E-06	5.13E-07	1.35E-03	7.52E-07	7.52E-02		7.
Cr	Min	0.81	1.16E-06	5.80E-07	3.87E-04	1.85E-07	3.08E-03		3.
	Max	3.11	4.44E-06	2.22E-06	1.48E-03	7.09E-07	1.18E-02		1.
	Mean	1.7825	2.55E-06	1.28E-06	8.50E-04	4.06E-07	6.77E-03		7.
Co	Min	0.68	9.71E-07		4.86E-05	3.88E-09	2.43E-07		4.
	Max	5.43	7.76E-06		3.88E-04	3.09E-08	1.93E-06		3.
	Mean	2.084	2.98E-06		1.49E-04	1.19E-08	7.44E-07		1.
As	Min	0.22	3.14E-07	4.71E-10	1.05E-03	3.76E-08	3.06E-04	1.38E-01	1.
	Max	1.51	2.16E-06	3.24E-10	7.20E-03	2.58E-07	2.10E-03	9.40E-01	9.
	Mean	1.055	1.51E-06	2.27E-10	5.03E-03	1.80E-07	1.46E-03	6.59E-01	6.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

This study evaluated the concentrations of lead (Pb), chromium (Cr), cobalt (Co), cadmium (Cd), and arsenic (As) in soil and water samples collected from Ipata Oloje, in Kwara State, Nigeria. Analytical results revealed distinct distribution patterns: sediment samples contained the highest Pb levels and the lowest Cd concentrations, while water samples exhibited peak Co values with Cd being least prevalent.

Ecological risk assessment using geo-accumulation indices demonstrated that the measured heavy metal concentrations in soil did not exceed critical thresholds, suggesting negligible ecological impacts. Water quality analysis focused on human health risks through two primary exposure pathways: ingestion and dermal contact. Carcinogenic risk assessments yielded values well below the 1.0×10^{-6} safety benchmark established by USEPA. Concurrently, the Hazard Index (HI) for non-carcinogenic effects remained below 1.0 (<1), indicating no significant acute or chronic health threats from water consumption or contact.

Soil risk assessments mirrored these findings for non-carcinogenic effects, with HI values <1.0 for both ingestion and dermal routes. Cancer risks from incidental soil ingestion were also within safe limits ($<1.0\times10^{-6}$). However, arsenic concentrations in

soil posed potential carcinogenic risks through dermal absorption, with calculated risk values approaching the 1.0×10^{-4} concern threshold. This specific finding warrants attention as prolonged skin contact with contaminated soil may increase cancer susceptibility among residents.

The spatial distribution of heavy metals strongly correlated with proximity to the automobile spare parts and recycling park. Diagnostic ratios and multivariate analysis identified vehicular emissions (Pb), welding residues (Cr, Co), and improper waste disposal (Cd, As) as primary contamination sources. The observed metal enrichment factors (EF > 5 for Pb and As) confirm anthropogenic dominance over natural geochemical backgrounds.

5.2 RECOMMENDATION

Recommendations:

1. **Remediation:** Soil stabilization (e.g., phosphate-based immobilization) and targeted wastewater treatment at industrial discharge points should be prioritized to reduce heavy metal mobility.
2. **Research Expansion:** Future work should integrate **mass flux modeling** with geospatial analysis to predict contamination hotspots and validate remediation efficacy.

3. **Health Surveillance:** Biomonitoring of vulnerable populations (e.g., spare part vendors) for Pb and As exposure is critical, given their elevated ADI and dermal risks.

4. **Regulatory Action:** Stakeholders must enforce stricter waste disposal guidelines and incentivize eco-friendly practices in auto-recycling industries.

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