ASSESSMENT OF SPATIAL DISTRIBUTION AND BIOACCUMULATION OF HEAVY METALS IN URBAN SOILS AND EARTHWORMS (*Aporrectodea longa*) IN BENIN CITY, NIGERIA: A COMPARATIVE STUDY OF BOTANICAL GARDEN, INDUSTRIAL ZONE AND AUTO- WORKSHOP AREAS

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A PROJECT WORK SUBMITTED TO THE DEPARTMENT OF ANIMAL AND ENVIRONMENTAL BIOLOGY, FACULTY OF LIFE SCIENCES, UNIVERSITY OF BENIN, BENIN CITY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF SCIENCE IN ANIMAL AND ENVIRONMENTAL BIOLOGY(BSCAEB)

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CERTIFICATION

This is to certify that this project was carried out by **OKOH VICTORIA OSAS** of the Department of Animal and Environmental Biology, Faculty of Life Sciences, University of Benin, Benin City.

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DR.0.C. ASEMOTA (Project Supervisor)	DATE
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PROF. MYKE .O. OMOGBERALE (Head of Department)	DATE

DEDICATION

This work is dedicated to God Almighty.

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I express profound gratitude to God Almighty for guiding me throughout this project research work.

My heartfelt appreciation goes to my loving family: my mother, Mrs. Hosanna Okoh, and brother, Mr. Michael Okoh, for their unwavering prayers, love, and support. I'm also grateful to my amazing sisters, Mrs. Gloria, Miss Ozioma, and Miss Dorinda.

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In conclusion, this project is a culmination of collective efforts. I am deeply appreciative of everyone who played a role in its realization. Thank you all for your invaluable contributi

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ABSTRACT

This study evaluates heavy metal contamination in soils and earthworms (*Aporrectodea longa*) across three distinct sites—a botanical garden, an automobile repair workshop, and an industrial zone—to assess site-specific pollution impacts. Soil and earthworm samples were analyzed for zinc (Zn), copper (Cu), manganese (Mn), cobalt (Co), lead (Pb), cadmium (Cd), nickel (Ni), and iron (Fe). Results revealed stark contrasts: the industrial zone exhibited the highest contamination, with Cd averaging 0.2700 mg/kg in soil (peaking at 0.5250 mg/kg) and 0.01500 mg/kg in earthworms, exceeding regulatory thresholds. The automobile workshop showed elevated Pb (0.02100 mg/kg in soil) linked to vehicular emissions, while the botanical garden had relatively lower metal levels (Zn: 1.370 mg/kg in soil), though earthworms still accumulated significant Fe (3.342 mg/kg) and Cd (0.01450 mg/kg). Earthworm bioaccumulation patterns mirrored soil contamination, with industrial earthworms retaining hazardous Pb (0.03150 mg/kg) and Cd, underscoring their role as bioindicators. The automobile workshop's earthworms exhibited suppressed metal uptake (Zn: 0.3600 mg/kg vs. soil Zn: 1.661 mg/kg), suggesting behavioral avoidance or toxicity effects. Conversely, botanical garden earthworms demonstrated moderate bioaccumulation despite lower soil pollution, hinting at atmospheric deposition. These findings highlight the industrial zone as a critical hotspot, with Cd posing severe ecological and human health risks due to its carcinogenic potential. The study advocates for urgent remediation in industrial areas, stricter regulation of automotive waste, and expanded use of earthworms in pollution monitoring. By linking land use to metal bioavailability, this research provides actionable insights for urban planning and environmental policy.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Heavy metal contamination in soil is a significant environmental concern, posing risks to ecosystem stability and human health. Sources of heavy metals include industrial emissions, vehicular exhaust, agricultural runoff, and improper waste disposal (Ahmed Alengebawy *et al.*, 2021; Alloway, 2013). Common contaminants include lead (Pb), cadmium (Cd), zinc (Zn), and copper (Cu), which are non-biodegradable and persist in the environment (Sandeep Kumar et al., 2019). These metals accumulate in soil, affecting soil organisms, plant health, and potentially entering the food chain (Changfeng Li *et al.*, 2019). Urban areas are particularly susceptible to contamination from traffic and other sources (Alloway, 2013). The impacts of heavy metals on soil biological activities and microbial processes can be severe (Sandeep Kumar *et al.*, 2019). Various remediation techniques, including chemical, physical, and biological methods, have been developed to address soil contamination, with phytoremediation emerging as a promising, cost-effective approach (Changfeng Li *et al.*, 2019).

Earthworms are crucial bioindicators of soil health and contamination due to their sensitivity to pollutants and ability to bioaccumulate heavy metals (Usmani and Kumar, 2015; Georgescu and Weber, 2009). They play a vital role in soil structure, fertility, and microbial activity (Georgescu and Weber, 2009). Earthworms exhibit various behavioral, physiological, and biochemical responses to soil contaminants, making them effective for assessing soil toxicity (Bhowmik *et al.,* 2022). Heavy metals can negatively impact earthworms at multiple levels, including enzyme inhibition, DNA damage, reduced survival, growth, and reproduction, and altered behavior (Yadav *et al.*, 2023). These effects can have significant consequences for earthworm communities and overall ecosystem stability (Yadav *et al*., 2023). Common species used in ecotoxicological studies include *Eisenia fetida*, *Eisenia andrei*, *Lumbricus terrestri*s, and *Lumbricus rubellus* (Georgescu and Weber, 2009). Various standardized and non-standardized tests are employed to evaluate earthworm responses to soil pollution, providing valuable insights into soil health and contamination levels (Georgescu and Weber, 2009).

Earthworms, particularly species like *Aporrectodea longa*, have emerged as reliable bioindicators for heavy metal contamination in soils due to their widespread distribution and capacity to bioaccumulate pollutants (Usmani and Kumar, 2015; Nei *et al*., 2009). These organisms accumulate metals in their chloragogenous tissues, making them effective ecological indicators of soil pollution (Usmani and Kumar, 2015). Various species, including A. *caliginosa*, A. *rosea*, and L. *terrestris*, have shown high accumulation of metals like zinc and copper in contaminated soils (Nei *et al*., 2009). Researchers have identified several biomarkers in earthworms that are sensitive to heavy metal exposure, such as glutathione-S-transferase, catalase, and acetylcholinesterase (Georgescu *et al*., 2011). These biomarkers can be used to assess soil pollution levels. The use of earthworms as bioindicators is particularly relevant given the increasing soil contamination from industrial activities, agricultural practices, and urban waste (Lionetto *et al*., 2012).

1.2 Rationale of Study

Heavy metal contamination in soil has become a global environmental concern, particularly affecting agricultural product safety (Li *et al.,* 2019). Common toxic metals include cadmium, mercury, arsenic, lead, and chromium (Shukla and Jain, 2020; Ingle *et al*., 2024). These pollutants enter soil ecosystems through natural processes and human activities, posing significant health risks due to potential accumulation in the food chain (Li *et al*., 2019). Various remediation methods have been developed, including chemical, physical, and biological approaches (Shukla and Jain, 2020). Phytoremediation has emerged as a promising, cost-effective, and environmentally friendly alternative, with over 500 plant taxa identified as hyperaccumulators of one or more metals (Li *et al*., 2019; Ingle *et al*., 2024). However, challenges remain, such as high expenses, processing duration, and geological issues (Rajendran *et al.,* 2021). Future research should focus on integrating biotechnological approaches with multidisciplinary studies to enhance plant tolerance and reduce toxic metal accumulation in soils (Li *et al*., 2019; Ingle *et al.,* 2024).

Heavy metal contamination in soils around auto-repair workshops is a significant environmental concern in Nigerian cities. Studies in Iwo and Benin City have found elevated levels of metals like Pb, Zn, Ni, Cr, and Hg in workshop soils compared to control sites (Ipeaiyeda and Dawodu, 2008; Anegbe *et al.,* 2016). The contamination often exceeds international thresholds for agricultural use and shows a decreasing trend with soil depth (Ipeaiyeda and Dawodu, 2008). While non-carcinogenic risks for adults and children are generally low, ingested nickel poses a potential carcinogenic risk to children (Enuneku *et al*., 2022). Soil samples from workshops across Benin City revealed varying levels of heavy metals, with higher concentrations in topsoil compared to samples taken 30m away (Bala *et al.,* 2019). These studies highlight the need for regular assessment and management of polluted areas, especially in rapidly growing urban centers with numerous small-scale enterprises (Anegbe *et al.,* 2016).

Heavy metals in soil pose significant threats to earthworms, crucial organisms for soil health and ecosystem functioning (Seribekkyzy *et al.,* 2022; Yadav *et al*., 2023). These contaminants can bioaccumulate in earthworms, causing detrimental effects at various organizational levels, including reduced enzyme activity, DNA damage, and decreased survival, growth, and reproduction (Yadav *et al*., 2023). The impact of heavy metals on earthworms varies across different ecosystems, with urban environments typically showing lower earthworm diversity and abundance compared to natural habitats (Seribekkyzy *et al.,* 2022). Earthworms' sensitivity to soil contamination makes them valuable bioindicators of environmental pollution (Parihar *et al.,* 2019). While earthworms can accumulate heavy metals, potentially aiding in soil remediation, their ability to do so is influenced by various factors, including their biological characteristics and habitat (Karaca *et al.,* 2010). The negative effects of heavy metals on earthworms can have far-reaching consequences for soil fertility, nutrient cycling, and overall ecosystem stability (Yadav *et al*., 2023; Parihar *et al*., 2019).

Earthworms play a crucial role in soil ecosystems, enhancing soil properties and serving as bioindicators of environmental contamination (Kapil Parihar *et al*., 2019). However, heavy metal pollution poses a significant threat to earthworm populations and soil health. Earthworms bioaccumulate heavy metals in their tissues, particularly in chloragogenous cells, making them valuable indicators of soil contamination (Usmani and Kumar, 2015). Studies have shown that heavy metal concentrations in soil and earthworms decrease along pollution gradients, with pH inversely correlated to metal levels (Uzoije *et al*., 2013). Heavy metal toxicity in earthworms manifests at various levels, from enzyme inhibition and DNA damage to reduced survival, growth, and reproduction. These effects can have far-reaching consequences for terrestrial ecosystems, impacting community stability and overall ecological health (Yadav *et al.,* 2023). Understanding heavy metal accumulation in earthworms is crucial for assessing ecological risks and developing effective soil management strategies.

1.3 Aim and Objectives

1.3.1 Aim

To investigate the site-specific impacts of heavy metals on soil ecosystems using the earthworm species *Aporrectodea longa* as a bioindicator.

1.3.2 Objectives

The objectives of this study were to:

1. Evaluate the concentration of heavy metals in soil across different environments.
2. Analyze the bioaccumulation of heavy metals in earthworm tissues at each site, providing insights into the bioavailability of these contaminants.
3. Conduct human health risk assessments based on soil and earthworm metal concentrations, focusing on exposure pathways relevant to vulnerable populations.
4. Perform ecological risk assessments to determine the potential impacts of heavy metal contamination on soil organisms and ecosystem health.
5. Identify spatial patterns in soil contamination and their correlation with specific anthropogenic activities.
6. To provide recommendations for soil management and remediation strategies based on site-specific risk profiles.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview Of Heavy Metal Contamination In Soils

Heavy metal contamination in soils is a critical environmental issue with serious implications for human health, ecosystem stability, and agricultural productivity. Unlike organic pollutants, heavy metals are non-biodegradable and can persist in the environment for extended periods, leading to bioaccumulation in plants and animals (Alloway, 2013). The presence of heavy metals in soils is influenced by both natural processes and anthropogenic activities, including industrialization, urbanization, and agricultural practices (Kabata-Pendias, 2011).

In Nigeria, heavy metal pollution has become a significant concern, particularly in urban and industrial areas where waste disposal, mining, and vehicle emissions contribute to soil contamination (Adebisi et al., 2017). Residential gardens, industrial zones, auto-workshops, and school grounds are particularly vulnerable to heavy metal accumulation, which can affect soil biota, reduce soil fertility, and pose health risks to humans and animals (Adefemi and Awokunmi, 2010).

The use of soil-dwelling organisms, such as earthworms, as bioindicators has gained increasing attention in soil pollution studies. Earthworms, particularly *Aporrectodea longa*, play a crucial role in soil ecosystems by influencing soil aeration, organic matter decomposition, and nutrient cycling (Edwards and Bohlen, 1996). However, their ability to bioaccumulate heavy metals makes them valuable in assessing soil contamination levels in different environments (Spurgeon and Hopkin, 1996).

2.2 Sources and Pathways of Heavy Metal Pollution in Terrestrial Environments

Heavy metals enter soils through various natural and anthropogenic sources and follow different pathways before becoming bioavailable for plant and animal uptake. Understanding these sources and pathways is crucial for assessing the extent of contamination and developing effective remediation strategies.

2.2.1 Natural Sources of Heavy Metal Contamination

Heavy metals naturally occur in the Earth's crust and are introduced into the soil through processes such as:

a) Weathering of Parent Rocks

The weathering of metal-bearing rocks releases heavy metals into soils, particularly in regions with high mineral deposits (Kabata-Pendias and Pendias, 2011). In Nigeria, areas such as Jos and Zamfara are naturally rich in lead (Pb), zinc (Zn), and other metals, leading to high background concentrations in local soils (Adamu et al., 2015).

b) Volcanic Eruptions and Atmospheric Deposition

Volcanic activity releases heavy metals into the atmosphere, which later settle on soil surfaces through precipitation and dust deposition (Alloway, 2013). Although volcanic activity is minimal in Nigeria, airborne dust from the Sahara Desert has been found to contribute to metal deposits in soils (Nwachukwu et al., 2010).

2.2.2 Anthropogenic Sources of Heavy Metal Contamination

Human activities significantly contribute to heavy metal pollution, particularly in urban and industrial environments. The major anthropogenic sources include:

a) Industrial Activities and Waste Disposal

Industries release heavy metals into the environment through air emissions, wastewater discharge, and improper solid waste disposal. In Nigeria, industrial hubs such as Lagos, Kano, and Port Harcourt have been identified as hotspots for heavy metal contamination due to inadequate waste management (Adekola et al., 2018). Common industrial pollutants include cadmium (Cd) from battery production, lead (Pb) from paint industries, and mercury (Hg) from petrochemical processes (Iwegbue et al., 2013).

b) Mining and Smelting Operations

Mining is a major source of heavy metal pollution in Nigeria. Artisanal and large-scale mining activities release toxic metals such as lead, arsenic (As), and mercury into surrounding soils (Obaje, 2009). The lead poisoning crisis in Zamfara State, linked to illegal gold mining, exemplifies the severe health and environmental impacts of heavy metal contamination (UNEP, 2016).

c) Agricultural Practices

The application of phosphate fertilizers, pesticides, and herbicides introduces heavy metals like lead, cadmium, and arsenic into agricultural soils. In Nigeria, studies have reported elevated heavy metal concentrations in farmlands irrigated with contaminated water (Ogunlaja and Ogunlaja, 2020). Additionally, poultry and livestock manure may contain high levels of copper (Cu) and zinc (Zn), further contributing to soil contamination (Akinola et al., 2010).

d) Automobile Workshops and Traffic Emissions

Auto-mechanic workshops are significant sources of soil contamination due to the disposal of used engine oil, lubricants, and metal scraps. Studies in Nigeria have shown high levels of lead, cadmium, and chromium in soils surrounding auto-repair shops (Odewande and Abimbola, 2008). Traffic-related pollution, including wear and tear of tires and brakes, also contributes to heavy metal accumulation in roadside soils (Nriagu et al., 1996).

e) Urbanization and Municipal Waste

The indiscriminate disposal of municipal waste, including e-waste and medical waste, leads to soil contamination. Open dumpsites often contain high levels of lead, mercury, and other metals due to the breakdown of electronic components and batteries (Ogundiran and Afolabi, 2008). In Nigeria, informal e-waste recycling sites in Lagos have been linked to severe heavy metal contamination in surrounding soils (Iwegbue et al., 2013).

2.2.3 Pathways of Heavy Metal Pollution in Terrestrial Environments

Once introduced into soils, heavy metals follow different pathways that influence their distribution, mobility, and bioavailability:

a) Atmospheric Deposition

Heavy metals emitted from industrial processes, vehicle exhaust, and open burning of waste settle onto soil surfaces through precipitation and dust accumulation (Fernández-Espinosa et al., 2002).

b) Leaching and Groundwater Contamination

Heavy metals can leach from contaminated soils into groundwater, especially in regions with acidic or sandy soils (Sipos et al., 2008). This poses a risk to drinking water sources, as seen in parts of northern Nigeria where arsenic contamination has been reported (Adamu et al., 2015).

c) Runoff into Surface Waters

During rainfall, heavy metals from contaminated soils can be transported into rivers, lakes, and wetlands, impacting aquatic ecosystems and drinking water supplies (Adebisi et al., 2017).

d) Bioaccumulation in Soil Organisms

Soil-dwelling organisms, such as earthworms, absorb heavy metals from contaminated soils. *Aporrectodea longa* has been widely used as a bioindicator in pollution studies due to its ability to accumulate heavy metals in its tissues, thereby reflecting soil contamination levels (Spurgeon and Hopkin, 1996).

e) Plant Uptake and Entry into the Food Chain

Heavy metals absorbed by plants can enter the food chain, posing health risks to humans and animals (Ghosh and Singh, 2005). Studies in Nigeria have reported elevated levels of cadmium and lead in vegetables grown near industrial zones (Akinola et al., 2010).

2.3 Anthropogenic Contributions to Heavy Metal Accumulation in Soils

Anthropogenic activities are the primary drivers of heavy metal contamination in soils, especially in urban, industrial, and agricultural settings. Unlike naturally occurring heavy metals, which are often locked in stable mineral forms, anthropogenic contributions increase metal bioavailability, leading to higher risks of environmental pollution (Kabata-Pendias, 2011). In Nigeria, the rapid expansion of industries, urbanization, and improper waste disposal have significantly exacerbated soil contamination issues (Adekola et al., 2018).

Major Anthropogenic Sources of Heavy Metal Accumulation in Nigeria

2.3.1 Mining and Mineral Processing

Mining activities are a major source of heavy metal contamination in Nigeria. The extraction and processing of minerals such as gold, lead, and zinc result in the release of hazardous metals into soils (Adamu et al., 2015). In Zamfara State, illegal gold mining led to a severe lead (Pb) poisoning crisis, affecting both the environment and human populations (UNEP, 2016). Similarly, tin mining in Jos has resulted in long-term contamination of local soils with arsenic (As), cadmium (Cd), and other metals (Obaje, 2009).

2.3.2 Industrial Emissions and Waste Disposal

Industries release heavy metals through air emissions, wastewater discharge, and solid waste dumping. Industrial areas in Lagos, Kano, and Port Harcourt have been identified as hotspots for soil contamination due to improper waste disposal practices (Iwegbue et al., 2013). Lead (Pb) and cadmium (Cd) from battery manufacturing, chromium (Cr) from tanneries, and mercury (Hg) from chemical industries are among the most prevalent contaminants (Adekola et al., 2018).

2.3.3 Agricultural Activities

The excessive use of chemical fertilizers, pesticides, and herbicides contributes to heavy metal accumulation in farmlands. Phosphate fertilizers, commonly used in Nigeria, contain trace amounts of cadmium and lead, which gradually accumulate in the soil (Ghosh and Singh, 2005). Additionally, irrigation with untreated wastewater introduces metals such as chromium (Cr) and mercury (Hg) into agricultural soils (Ogunlaja and Ogunlaja, 2020).

2.3.4 Automobile and Auto-Workshop Activities

Auto-repair workshops contribute significantly to heavy metal contamination through the disposal of used engine oil, metal scraps, and worn-out tires. Studies in Nigerian urban centers have shown that soils in and around auto-mechanic workshops contain elevated levels of lead (Pb), zinc (Zn), and chromium (Cr) (Odewande and Abimbola, 2008).

2.3.5 Municipal Waste and E-Waste Dumping

The indiscriminate disposal of solid waste, including electronic waste (e-waste), significantly increases soil heavy metal levels. Lagos, as Nigeria’s commercial hub, has numerous informal e-waste recycling sites where discarded electronic components release lead, cadmium, and mercury into the soil (Ogundiran and Afolabi, 2008). Open burning of municipal waste further exacerbates contamination through atmospheric deposition (Nwachukwu et al., 2010).

2.4 Regional And Global Studies On Soil Heavy Metal Contamination

Heavy metal contamination of soils is a global concern, with studies reporting widespread pollution in both developing and developed countries.

2.4.1 Regional Studies in Nigeria

Numerous studies have documented soil heavy metal contamination in Nigeria. For example Ogunlaja and Ogunlaja (2020) reported high levels of cadmium (Cd) and lead (Pb) in agricultural soils irrigated with wastewater in Lagos. Adebisi et al. (2017) analyzed soil samples from industrial areas in Ibadan and found excessive concentrations of chromium (Cr) and zinc (Zn), posing potential health risks. Akinola et al. (2010) investigated roadside soil contamination in Lagos and found that lead (Pb) levels exceeded safe limits due to vehicular emissions.

2.4.2 Global Studies on Heavy Metal Contamination

Several international studies have reported similar findings in different parts of the world:

Sipos et al. (2008) found heavy metal contamination in European farmlands due to long-term use of phosphate fertilizers. Fernández-Espinosa et al. (2002) reported severe lead (Pb) contamination in urban soils of Spain due to industrial emissions and vehicle exhaust.

Ghosh and Singh (2005) reviewed global trends in phytoremediation, highlighting heavy metal pollution hotspots in Asia, Europe, and Africa. These studies emphasize the urgent need for soil remediation and pollution control measures, particularly in rapidly developing countries like Nigeria.

2.5 Earthworms as Bioindicators of Heavy Metal Pollution

Earthworms are widely used as bioindicators in environmental pollution studies due to their sensitivity to soil contaminants and their ability to bioaccumulate heavy metals (Spurgeon and Hopkin, 1996).

2.5.1 Biological Importance of Earthworms in Soil Ecosystems

Earthworms play a crucial role in maintaining soil health and ecosystem balance. Their activities contribute significantly to soil aeration, organic matter decomposition, microbial activity, and overall soil fertility, making them essential biological agents for sustainable agriculture and environmental stability.

a) Soil Aeration and Structure Improvement

One of the primary benefits of earthworm activity is the enhancement of soil aeration and structure. As earthworms burrow through soil layers, they create interconnected tunnels that facilitate air circulation and improve oxygen availability for plant roots and soil microorganisms. These burrows also enhance water infiltration, reducing surface runoff and soil erosion, thus improving soil stability (Edwards and Bohlen, 1996). Moreover, their movement helps in breaking up compacted soil, making it more permeable and suitable for root penetration, which is crucial for crop growth and productivity.

b) Organic Matter Decomposition and Nutrient Cycling

Earthworms play a vital role in the decomposition of organic matter by consuming decaying plant material and animal residues. Through their digestive processes, organic residues are broken down into finer particles, enriching the soil with essential nutrients such as nitrogen, phosphorus, and potassium. This natural composting process significantly enhances soil fertility by increasing the availability of nutrients in a form that plants can readily absorb (Lavelle et al., 2006). Additionally, earthworm castings (excreta) are rich in humus and beneficial microorganisms, which further contribute to the overall improvement of soil quality.

c) Microbial Activity Enhancement

The presence of earthworms in the soil is associated with increased microbial activity, which is critical for soil nutrient cycling. As earthworms consume organic matter, their digestive system fosters the proliferation of beneficial microbes, leading to enhanced decomposition and organic matter mineralization. This microbial stimulation boosts soil enzyme activity, accelerating the breakdown of complex organic compounds into simpler forms that plants can utilize efficiently (Brown et al., 2000). Furthermore, the mucus secreted by earthworms while burrowing serves as a habitat for beneficial microbes, supporting a thriving soil microbiome.

d) Soil Fertility and Agricultural Productivity

By improving soil aeration, enhancing microbial activity, and enriching soil with essential nutrients, earthworms directly contribute to increased agricultural productivity. Their role in nutrient cycling ensures a sustainable supply of minerals necessary for plant growth (Gazi et al., 2024). In traditional and modern Nigerian farming systems, the presence of earthworms is often associated with fertile lands, making them valuable indicators of soil health. Additionally, vermicomposting—an agricultural practice that involves using earthworms to process organic waste into nutrient-rich compost—is gaining popularity as a sustainable means of improving soil quality and boosting crop yields (Ahmed and Al-Mutairi, 2022).

e) Environmental Benefits and Ecosystem Stability

Beyond agriculture, earthworms contribute to broader environmental stability by promoting soil carbon sequestration and mitigating climate change effects (Angst et al., 2019). Their ability to break down organic matter into stable forms of carbon helps in reducing greenhouse gas emissions and improving soil organic matter content. In Nigeria, where soil degradation due to over-farming and deforestation is a major challenge, the role of earthworms in restoring soil health is increasingly being recognized (Zhang et al., 2013).

2.6 Sensitivity of Earthworms to Heavy Metals in Polluted Environments

Heavy metals such as lead (Pb), cadmium (Cd), copper (Cu), zinc (Zn), chromium (Cr), and manganese (Mn) are persistent environmental pollutants that pose serious ecological and human health risks. Earthworms have been found to accumulate these metals in their tissues, reflecting the contamination level of their habitat (Nahmani et al., 2007). Several Nigerian studies have examined the sensitivity of earthworms to heavy metals, highlighting their bioaccumulative tendencies and physiological responses.

A study conducted by Adeyemi et al. (2018) in Abeokuta, southwestern Nigeria, assessed the bioaccumulation of heavy metals in indigenous earthworm species collected from abattoir soils. The research covered three sites: Lafenwa, Gbonogun, and Madojutimi. The results showed that the concentration of heavy metals in the soil was significantly high, with lead (Pb), cadmium (Cd), and manganese (Mn) being the most prevalent contaminants. The earthworms in these areas exhibited high levels of bioaccumulation, particularly for cadmium (Cd), which had a bioaccumulation factor greater than one. This suggests that cadmium is more readily absorbed and retained by earthworms, making them particularly sensitive to its presence in soil (Adeyemi et al., 2018).

In another Nigerian study, Alatise et al. (2020) investigated the effects of heavy metals on *Eudrilus eugeniae*, an earthworm species commonly used in vermicomposting. The study exposed the earthworms to water and sediments from the Ogun River, a body of water known for its high pollution levels due to industrial and domestic effluents. The results indicated that the earthworms accumulated significant levels of lead (Pb), copper (Cu), and zinc (Zn), confirming their sensitivity to these metals and potential use in pollution monitoring. The study also noted physiological stress responses in the earthworms, including reduced growth rates and increased mortality, further supporting their role as sensitive indicators of heavy metal pollution (Alatise et al., 2020).

Another notable study by Adebayo et al. (2019) examined the bioaccumulation of heavy metals in earthworms collected from mining areas in Zamfara State, Nigeria. The findings indicated that earthworms exposed to mining-contaminated soils accumulated substantial levels of lead (Pb) and arsenic (As). This was consistent with previous reports highlighting the impact of mining activities on soil health and the risk of bioaccumulation in soil organisms. The study concluded that earthworms from these sites had significantly higher metal concentrations compared to those from uncontaminated areas, reinforcing their utility as bioindicators of metal pollution (Adebayo et al., 2019).

2.7 Role of Earthworms in Biomonitoring Heavy Metal Contamination

The ability of earthworms to bioaccumulate heavy metals has led to their widespread use in biomonitoring studies. Their burrowing and feeding behaviors facilitate the ingestion of contaminated soil particles, leading to the accumulation of metals in their tissues, which can be analyzed to assess soil contamination levels (Morgan and Morgan, 1999). Studies in Nigeria have demonstrated the potential of earthworms as reliable bioindicators in different environments. A study by Ogunlade et al. (2021) investigated heavy metal contamination in soil and earthworms from the Isheri Cattle Market along the Ibadan-Lagos Expressway. The study found that earthworms accumulated significant amounts of Pb, Zn, Mn, Cu, and Cr, with lead (Pb) being the most prevalent. The concentration trend followed Pb > Zn > Mn > Cu > Cr > Cd, suggesting that lead was the most bioavailable heavy metal in the area. The researchers concluded that earthworms could serve as effective bio-monitors of heavy metal contamination in livestock-related environments, where soil pollution from waste disposal is a concern (Ogunlade et al., 2021). Similarly, research by Okoro et al. (2022) assessed heavy metal accumulation in earthworms found in sawmill vicinities. The study analyzed soil, plant, and earthworm samples for metal content and biochemical changes in the earthworms. The results showed significant bioaccumulation of lead (Pb) and cadmium (Cd) in earthworms, accompanied by alterations in their enzyme activity and oxidative stress markers. These findings highlight the potential of earthworms not only as indicators of metal pollution but also as early warning organisms for assessing environmental stress in polluted ecosystems (Okoro et al., 2022).

Another study by Bello et al. (2023) examined earthworm populations in school gardens in Lagos to determine their effectiveness in detecting heavy metal contamination from urban waste and vehicle emissions. The study found elevated levels of lead (Pb) and zinc (Zn) in earthworms from school grounds near busy roads. This underscores the importance of earthworms in monitoring pollution in urban settings, where children are at risk of exposure to contaminated soil (Bello et al., 2023).

2.8 Bioaccumulation of Heavy Metals in Soil-Dwelling Organisms

Soil-dwelling organisms play a vital role in maintaining soil health and ecosystem balance. However, due to increasing anthropogenic activities such as industrialization, mining, and the use of agrochemicals, heavy metal contamination in soils has become a significant environmental concern. Heavy metals such as lead (Pb), cadmium (Cd), arsenic (As), zinc (Zn), copper (Cu), and mercury (Hg) are non-biodegradable, persist in the environment for extended periods, and can be absorbed by soil organisms. One of the primary concerns associated with heavy metals is their bioaccumulation—the process by which organisms absorb contaminants at a rate faster than they can eliminate them.

Earthworms, insects, and other soil-dwelling organisms are widely recognized as bioindicators of heavy metal pollution due to their high sensitivity to metal accumulation. These organisms take up metals from their surroundings, which then accumulate in their tissues over time. According to Owa et al. (2013), earthworms are particularly susceptible to heavy metal bioaccumulation because they ingest large quantities of soil and are in constant contact with contaminated soil particles.

2.8.1 Bioaccumulation in Earthworms and Other Soil Organisms

Research has shown that heavy metals are taken up by earthworms through two primary pathways: ingestion and dermal absorption. When earthworms feed on organic matter in the soil, they inadvertently ingest metal-contaminated particles. Some of these metals bind to proteins within their bodies, while others accumulate in tissues. In addition, dermal absorption occurs when metals in soil pore water diffuse through the earthworm's skin.

A study conducted in Nigeria by Adeyemi and Olayemi (2016) analyzed the concentration of heavy metals in earthworms collected from agricultural and industrial areas. Their findings indicated significantly higher concentrations of Pb, Cd, and Cu in earthworms from industrial areas compared to those from agricultural soils. This suggests that industrial discharges contribute significantly to soil contamination.

Other soil-dwelling organisms, such as arthropods, fungi, and bacteria, also exhibit bioaccumulation tendencies. Ekpo et al. (2018) reported that termites in a mining-affected region in Northern Nigeria accumulated heavy metals in their bodies, demonstrating their potential role as bioindicators of pollution.

2.8.2 Implications of Bioaccumulation for Food Chains and Ecosystems

Bioaccumulation in soil organisms has broader ecological implications. Predatory organisms that feed on contaminated earthworms and insects—such as birds, amphibians, and small mammals—may experience secondary metal accumulation, a process known as biomagnification. This phenomenon leads to increased heavy metal concentrations at higher trophic levels, thereby posing risks to wildlife and even humans who consume these organisms. Furthermore, bioaccumulation in decomposers like earthworms affects soil fertility and microbial activity. Adediran et al. (2020) highlighted that excessive heavy metal accumulation alters enzymatic activities in earthworms, reducing their efficiency in organic matter decomposition and nutrient cycling.

2.9 Mechanisms of Metal Uptake in Earthworms

Pathways of Heavy Metal Absorption in Earthworms

Earthworms absorb heavy metals from contaminated soil primarily through two mechanisms:

a) Ingestion of Soil Particles – Earthworms ingest soil and organic matter as they burrow and feed. During digestion, heavy metals present in soil particles dissolve into the body fluids and enter the circulatory system. The metals may bind to proteins such as metallothioneins, which play a crucial role in detoxification and metal regulation (Spurgeon and Hopkin, 1999).

b) Dermal Absorption through the Cuticle – Earthworms have a thin, permeable cuticle that facilitates the uptake of dissolved metals from soil pore water. This mode of absorption depends on the metal’s solubility and the soil’s pH, organic matter content, and cation exchange capacity.

2.10 Human and Ecological Risks of Heavy Metal Pollution

Heavy metal pollution has become a critical environmental issue in Nigeria, primarily due to industrial activities, mining operations, and poor waste management practices. Heavy metals such as Lead (Pb), Cadmium (Cd), mercury (Hg), arsenic (As), chromium (Cr), and nickel (Ni) are non-biodegradable and persist in the environment, posing significant risks to both human and ecosystems. The risks associated with heavy metal combination range from acute toxicity to chronic health conditions in the human and severe ecological damage affecting soil quality, water bodies, biodiversity.

2.10.1 Toxicological Effects Of Heavy Metals On Humans And Ecosystems

Heavy metal pollution poses significant threats to human health and the environment. The toxicity of heavy metals depends on their chemical form, bioavailability, and exposure duration. Long-term exposure to heavy metals can cause various chronic diseases, including neurological disorders, organ damage, and developmental issues.

a) Human Health Risks

Lead (Pb): A neurotoxin that affects cognitive function, particularly in children. It also causes hypertension and kidney damage (WHO, 2020).

Cadmium (Cd): Associated with kidney dysfunction, skeletal damage, and reproductive issues.

Mercury (Hg): Known for its neurotoxic effects, leading to cognitive impairments and muscle tremors.

Arsenic (As): A carcinogen linked to skin, lung, and bladder cancer.

A study by Akinola et al. (2019) on residents living near metal-processing industries in Lagos found elevated blood lead levels, correlating with symptoms of lead poisoning such as memory loss and joint pain.

b) Ecological Risks

Heavy metal contamination affects soil microbiota, plant growth, and biodiversity. Olowoyo et al. (2021) reported that soil microbial communities in industrial zones exhibited reduced diversity due to high levels of copper (Cu) and Zinc (Zn) contamination. This disruption in microbial activity can lead to soil degradation, reduced organic matter decomposition, and decreased agricultural productivity.

In aquatic ecosystems, heavy metal runoff from contaminated soils can lead to bioaccumulation in fish and other aquatic organisms, further increasing the risk of biomagnification up the food chain.

2.11 Risk Assessment Frameworks for Evaluating Heavy Metal Exposure

Risk assessment is crucial in determining the potential health and environmental effects of heavy metal exposure. Standard risk assessment frameworks include:

1. Hazard Identification: Identifies specific heavy metals and their toxicological properties
2. Exposure Assessment: Evaluates contamination levels in air, water, soil, and food.
3. Dose-Response Assessment: Establishes the relationship between exposure levels and health outcomes.
4. Risk Characterization: Integrates hazard and exposure data to estimate the overall risk.

Several models have been developed to assess heavy metal risks, such as the USEPA Human Health Risk Assessment Model, which calculates non-carcinogenic and carcinogenic risks based on reference doses and exposure pathways.

In Nigeria, risk assessments have been conducted in industrial zones and mining areas. (Okonkwo et al., 2022) assessed soil contamination levels in auto-mechanic workshops in Ibadan and found that lead (Pb) and Cadmium (Cd) concentrations exceeded WHO safety limits, posing significant health risks to workers and resident.

CHAPTER THREE

METHODOLOGY

3.0 Study Area

This study was conducted in Benin City, the capital of Edo State, Nigeria. Benin City serves as a hub of diverse environments, making it an ideal location for investigating the site-specific effects of heavy metal pollution. The study area comprised various locations selected to represent different land uses that may influence heavy metal contamination.

The selected sites included:

1. Residential Garden – A serene green space within an urban neighborhood, representing residential exposure to potential pollutants.
2. Industrial Zone – A site with high industrial activity, where emissions, waste disposal, and effluents may contribute to heavy metal contamination.
3. Auto Workshop – An industrial area characterized by mechanical repairs and oil spills, serving as a potential source of heavy metal contamination.

These locations, spanning residential, educational, and industrial settings, provided a comprehensive framework for analyzing the site-specific effects of heavy metals in Benin City.

3.1 Sampling Methods

3.1.1 Soil Sample Collections

Soil samples were collected from various locations within Benin City, Edo State, Nigeria, representing diverse environmental settings, such as industrial zones, residential areas, and agricultural fields. The collection was carried out following standard soil sampling protocols to ensure representativeness and accuracy of the results.

1. **Preparation**: A total of 10 to 15 soil samples were collected from each study site. The sampling was conducted during the dry season to minimize the influence of rainfall on the metal content in the soil. For each location, soil was sampled at a depth of 0-15 cm using a stainless-steel auger, which was cleaned thoroughly between samples to avoid cross-contamination (Müller, 2004).
2. **Sample Handling**: The collected soil samples were air-dried in a shaded area to prevent decomposition and loss of volatile compounds. The samples were sieved using a 2 mm mesh to remove larger particles, such as stones and plant roots, ensuring that only fine soil particles were analyzed (Sparks, 2003).
3. **Digestion Process**: The soil samples (5g each) were subjected to digestion using the Aqua Regia method. The procedure involved adding 7.5 ml concentrated hydrochloric acid (HCl) and 2.5 ml concentrated nitric acid (HNO3) in a 3:1 ratio, to the soil samples placed in digestion tubes. The mixture was then heated in a water bath at 100°C for 2 hours, with intermittent shaking every 20 minutes. After cooling, the digests were filtered through Whatman filter paper into 25 ml volumetric flasks. The resulting filtrate was made up to the mark with distilled water for subsequent analysis using Atomic Absorption Spectroscopy (AAS) (Liu et al., 2008; USEPA, 1996).

3.1.2 Earthworm Sample Collection

Earthworm samples were collected from the same locations where soil samples were taken, particularly focusing on areas with potential contamination from anthropogenic activities such as agricultural fields, roadsides, and landfill sites. Earthworms, specifically *Aporrectodea longa*, were selected due to their prevalence in the region and their ability to bioaccumulate heavy metals from the soil (Gomez et al., 2015).

1. **Collection Method**: Earthworms were collected by hand-sorting the soil. The soil was gently excavated to a depth of approximately 20 cm, ensuring minimal disturbance to the worms. Care was taken to collect earthworms from different parts of the sampling locations to ensure that the samples were representative of the entire area (Bouche, 1977).
2. **Handling**: The earthworms were carefully placed in clean containers with moist soil to prevent desiccation during transportation to the laboratory. The samples were kept in a cool place to minimize stress and avoid any loss of metal contaminants from the worms.
3. **Digestion Process**: Upon arrival at the laboratory, the collected earthworms were weighed (5g each) and digested using 3 ml of concentrated nitric acid (HNO3). The worms were heated to dryness on a hot plate and re-dissolved in 2 ml of concentrated HNO3. The solution was made up to a 25 ml volume using distilled water. The resulting digests were stored in clean, labeled plastic containers for analysis of metal content using AAS.

3.2 Analysis

Both the soil and earthworm digests were analyzed for heavy metals, including Chromium (Cr), Cadmium (Cd), Lead (Pb), Nickel (Ni), Zinc (Zn), and Copper (Cu), using a Buck Scientific AAS Model 205A. The concentration of metals in each sample was determined by the absorption of light at specific wavelengths corresponding to the metals being analyzed

3.3 Quality Assurance / Quality Control

To ensure the dependability of the findings in this current research, we conducted suitable quality checks. We employed analytical-grade reagents for calibrating the instruments.

Additionally, we evaluated the precision and data credibility by calculating the coefficients of variation for duplicate analyses, which revealed variations of less than 10%.

3.4 Statistical Analysis

Data analysis was performed using the computer software EXCEL and Statistical package for social sciences (SPSS) version 20. One-way analysis of variance (ANOVA) was used to determine significant difference ($p < 0.05$) between groups. The results are presented as mean ± standard deviation. Duncan Multiple Range (DMR) Post Hoc test was used to find out homogenous subset within groups.

3.5 Sampling Labeling and Storage

Each sample container was labeled with a unique identifier including coordinates, samples type and sample date.

3.5.1 Soil Sample Storage

Soil samples were stored in clean, airtight containers to prevent contamination and water loss.

3.6 Sample Analysis

3.6.1 Heavy Metal Determination

Soil samples were prepared by homogenizing. Heavy metal concentrations in the soil samples were analyzed using appropriate techniques such as ICP – MS (Inductively Coupled Plasma Mass Spectrometry) and AAS (Atomic Absorption Spectroscopy).

3.7 Soil Sample Digestion

Soil samples were air-dried and sieved before digestion. A 5 g portion of each sample was weighed into a digestion tube, followed by the addition of 7.5 mL of concentrated hydrochloric acid (HCl) and 2.5 mL of concentrated nitric acid (HNO_3) in a 3:1 ratio, forming 10 mL of aqua regia. The digestion tube was covered and heated in a water bath at 100°C for 2 hours, with intermittent shaking every 20 minutes to ensure proper digestion. After cooling to room temperature, the digest was filtered through Whatman filter paper into a 25 mL standard volumetric flask. The filtrate was then diluted to the mark with distilled water and transferred into a plastic container for further analysis. Heavy metal concentrations, including chromium (Cr), cadmium (Cd), lead (Pb), nickel (Ni), zinc (Zn), and copper (Cu), were determined using a Buck Scientific Atomic Absorption Spectrophotometer (AAS) Model 205A.

3.8 Earthworm Digestion

The sampled earthworm species, *Aporectodea longa*, was analyzed for heavy metal accumulation. A 5 g portion of thawed earthworm tissue was digested using 3 mL of concentrated citric acid (HNO_3) and heated to dryness on a hot plate. The dried digest was then re-dissolved in 2 mL of concentrated HNO_3, after which the solution was diluted to 25 mL with distilled water. The prepared sample was stored in a clean plastic container for AAS analysis to determine heavy metal concentrations in the earthworm tissue.

CHAPTER FOUR

RESULTS

4.1 Results From The Samples Collected From The Botanical Garden At Ugbowo

4.1.1Soil Sample Collected At The Botanical Garden

Zinc (Zn) varied between 1.195 mg/kg and 1.545 mg/kg, with an average of 1.370 ± 0.1975 mg/kg. Copper (Cu) ranged from 0.7590 mg/kg to 0.9260 mg/kg, attaining a mean of 0.8425 ± 0.1184 mg/kg. Manganese (Mn) fluctuated between 0.3480 mg/kg and 0.3820 mg/kg, with an average of 0.3650 ± 0.0240 mg/kg. Cobalt (Co) values varied between 0.1350 mg/kg and 0.1765 mg/kg, yielding an average of 0.1558 ± 0.0293 mg/kg. Lead (Pb) concentrations remained stable at 0.03900 mg/kg. Cadmium (Cd) fluctuated between 0.01600 mg/kg and 0.01900 mg/kg, with an average of 0.01750 ± 0.002121 mg/kg. Iron (Fe) ranged from 2.043 mg/kg to 2.547 mg/kg, achieving a mean of 2.295 ± 0.357 mg/kg.

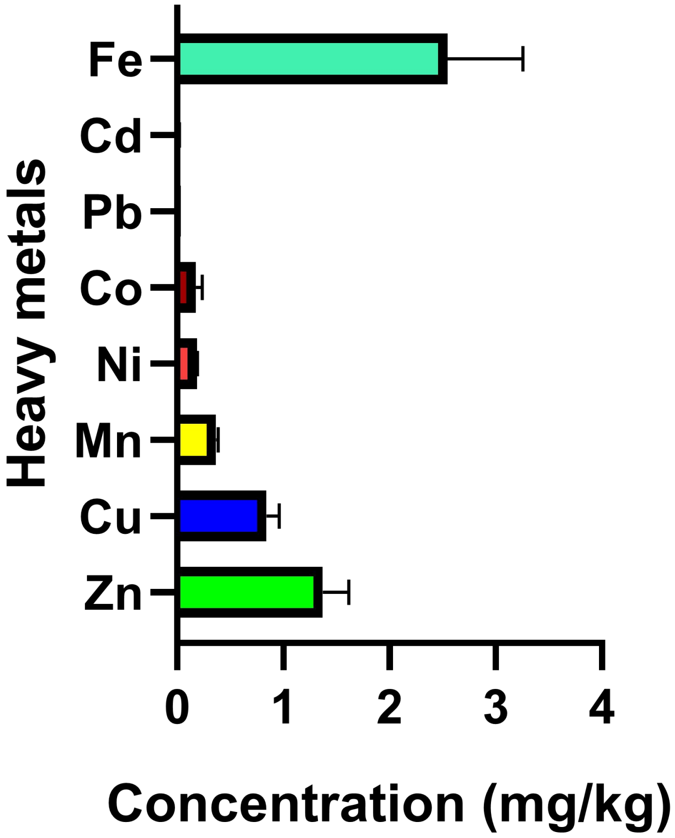

Fig 4.1.1 Heavy metals concentration in soil from botanical garden

4.1.2 Earthworm Sample Collected at the Botanical Garden

The concentrations of Zinc (Zn) in the botanical garden earthworm ranged from 1.376 mg/kg to 1.482 mg/kg, with a mean of 1.429 ± 0.07495 mg/kg. Copper (Cu) levels, on the other hand, varied between 0.6920 mg/kg and 0.7380 mg/kg, averaging 0.7150 ± 0.03253 mg/kg. Manganese (Mn) concentrations spanned from 0.2890 mg/kg to 0.3110 mg/kg, achieving a mean of 0.3000 ± 0.01556 mg/kg, while Nickel (Ni)was recorded between 0.1990 mg/kg and 0.2140 mg/kg, with a mean of 0.2065 ± 0.01061 mg/kg. Cobalt (Co) showed a narrower range, varying from 0.09900 mg/kg to 0.1070 mg/kg, and averaged 0.1030 ± 0.005657 mg/kg. Lead (Pb) concentrations extended from 0.03500 mg/kg to 0.03800 mg/kg, leading to a mean of 0.03650 ± 0.002121 mg/kg, and Cadmium (Cd) ranged from 0.01400 mg/kg to 0.01500 mg/kg, attaining an average of 0.01450 ± 0.0007071 mg/kg. Lastly, Iron (Fe) levels ranged from 3.218 mg/kg to 3.465 mg/kg, with a mean of 3.342 ± 0.1747 mg/kg.

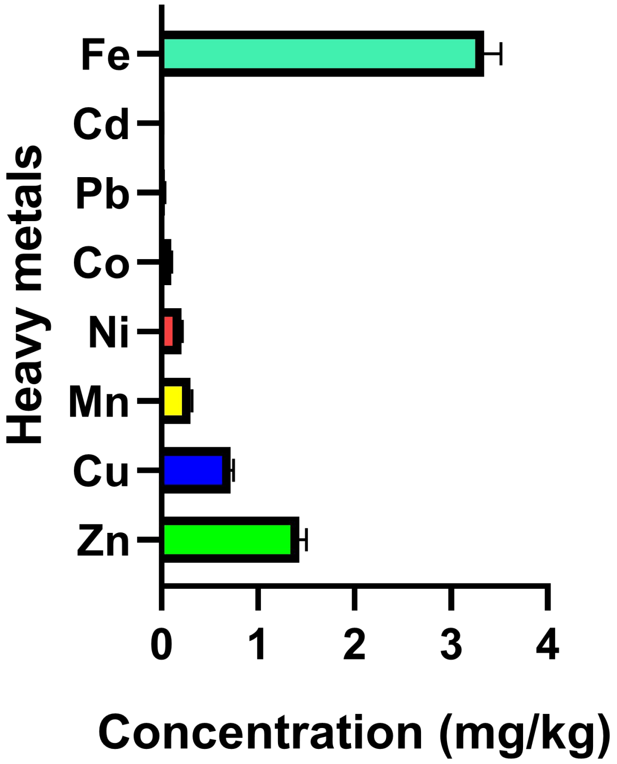

Fig 4.1.2 Heavy metal concentration in earthworm from botanical garden

4.2 Results from Automoble Repair Shop at Uwelu

4.2.1 Soil Sample Collected from Automobile Repair Shop

Zinc (Zn) varied between 1.649 mg/kg and 1.673 mg/kg, with a mean of 1.661 ± 0.01697 mg/kg. Copper (Cu) levels ranged from 0.8580 mg/kg to 0.8650 mg/kg, achieving a mean of 0.8615 ± 0.004950 mg/kg. Manganese (Mn) fluctuated between 0.3730 mg/kg and 0.3820 mg/kg, with an average of 0.3775 mg/kg ± 0.006364 mg/kg. Nickel (Ni) concentrations spanned from 0.1560 mg/kg to 0.1730 mg/kg, yielding a mean of 0.1645 mg/kg ± 0.01202 mg/kg. Copper (Cu) values ranged from 0.1960 mg/kg to 0.2750 mg/kg, attaining a mean of 0.2355 ± 0.05586 mg/kg. Lead (Pb) concentrations varied from 0.002000 mg/kg to 0.04000 mg/kg, leading to an average of 0.02100 ± 0.02687 mg/kg. Cadmium (Cd) ranged from 0.004000 mg/kg to 0.01600 mg/kg, with a mean of 0.01000 ± 0.008485 mg/kg. Iron (Fe) fluctuated between 2.421 mg/kg and 2.465 mg/kg, averaging 2.443 ± 0.03111 mg/kg.

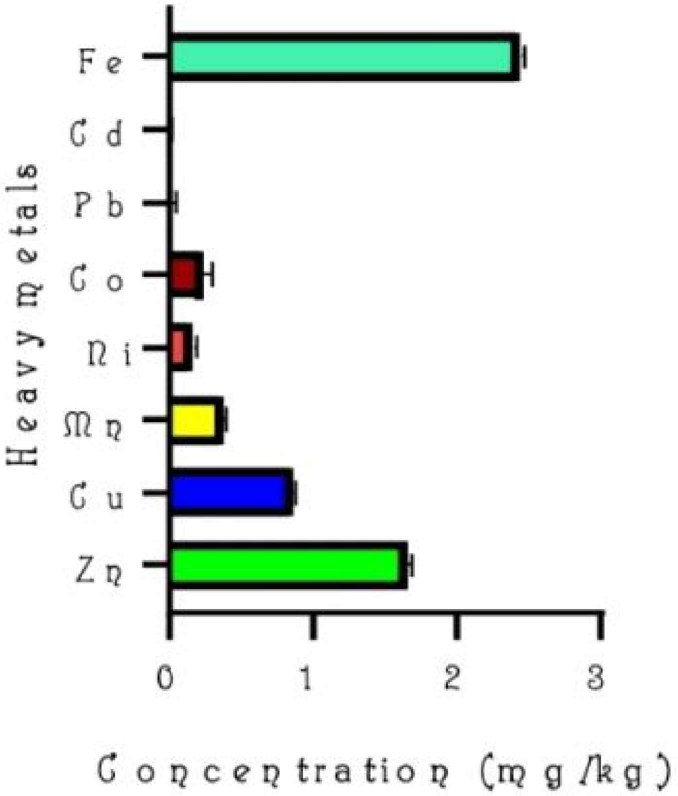

Fig 4.2.1 Heavy metal concentration in soil from automobile shop

4.2.2 Earthworm Sample Collected From Automobile Repair Shop

Zinc (Zn) levels ranged from 0.3510 mg/kg to 0.3690 mg/kg, with an average of 0.3600 ± 0.01273 mg/kg. Copper (Cu) varied between 0.1320 mg/kg and 0.1450 mg/kg, leading to a mean of 0.1385 ± 0.009192 mg/kg. Manganese (Mn) concentrations spanned from 0.06100 mg/kg to 0.06700 mg/kg, averaging 0.06400 ± 0.004243 mg/kg. Nickel (Ni) ranged from 0.02900 mg/kg to 0.03700 mg/kg, achieving a mean of 0.03300 ± 0.005657 mg/kg. Cobalt (Co) concentrations varied between 0.03800 mg/kg and 0.04300 mg/kg, with a mean of 0.04050 ± 0.003536 mg/kg. Lead (Pb) ranged from 0.01000 mg/kg to 0.01400 mg/kg, averaging 0.01200 ± 0.002828 mg/kg. Cadmium (Cd) fluctuated between 0.005000 mg/kg and 0.008000 mg/kg, with a mean of 0.006500 ± 0.002121 mg/kg. Iron (Fe) ranged from 0.7520 mg/kg to 0.7840 mg/kg, attaining a mean of 0.7680 ± 0.02263 mg/kg.

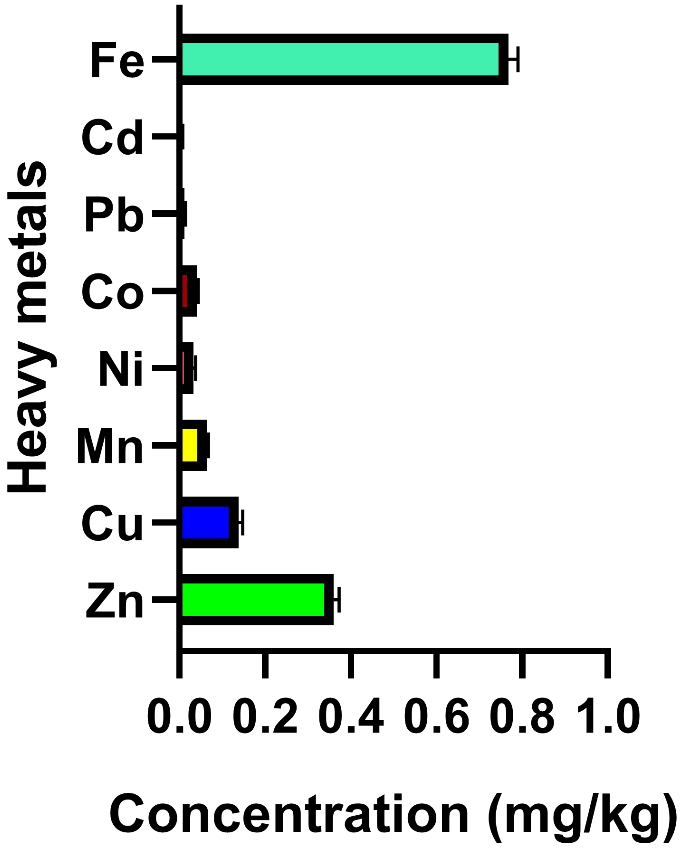

Fig 4.2.2 Heavy Metal Concentration In Earthworm From Automobile Shop

4.3 Results From Industrial Zone At Oluku

4.3.1 Soil Sample Collected From Industrial Zone

At the industrial zone site, Zinc (Zn) concentrations ranged from 0.3560 mg/kg to 0.6250 mg/kg, with a mean of 0.4905 ± 0.1902 mg/kg. Copper (Cu) levels varied between 0.08700 mg/kg and 0.1950 mg/kg, averaging 0.1410 ± 0.0764 mg/kg. Manganese (Mn) concentrations spanned from 0.04200 mg/kg to 0.1500 mg/kg, achieving a mean of 0.09600 ± 0.0764 mg/kg. Nickel (Ni) ranged from 0.03800 mg/kg to 0.08900 mg/kg, with a mean of 0.06350 ± 0.0361 mg/kg. Cobalt (Co) values fluctuated between 0.01600 mg/kg and 0.1280 mg/kg, yielding an average of 0.07200 ± 0.0792 mg/kg. Lead (Pb) concentrations varied from 0.008000 mg/kg to 0.02900 mg/kg, with a mean of 0.01850 ± 0.0149 mg/kg, while Cadmium (Cd) levels ranged from 0.01500 mg/kg to 0.5250 mg/kg, attaining an average of 0.2700 ± 0.3606 mg/kg. Iron (Fe) concentrations spanned from 0.7520 mg/kg to 1.194 mg/kg, with a mean of 0.9730 ± 0.3125 mg/kg.

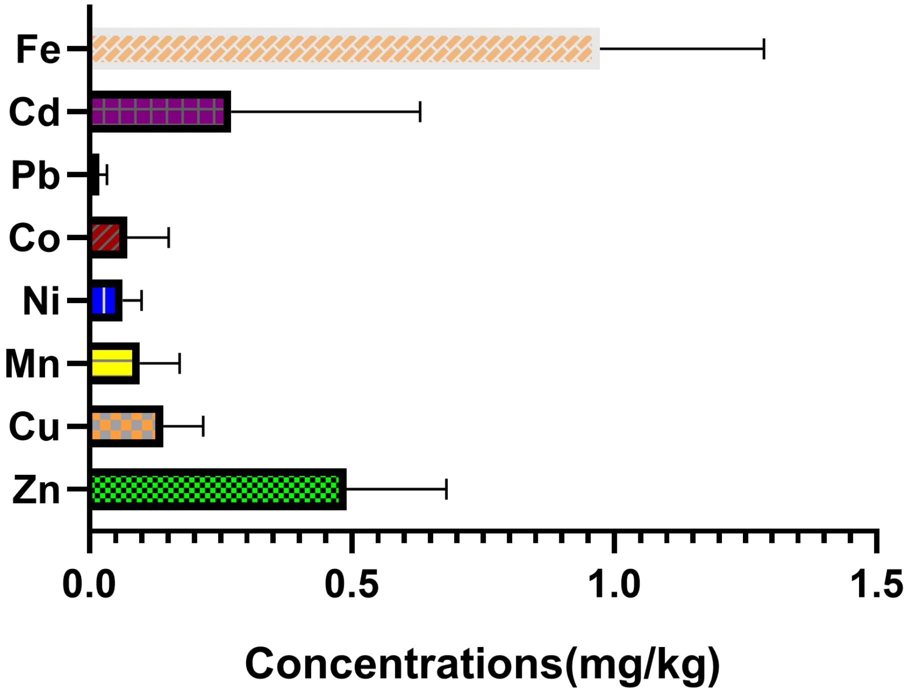

Fig 4.2.1 Heavy metal concentration in soil from industrial zone

4.3.2 Earthworm Sample Collected From Industrial Zone

At the Industrial Zone site, Zinc (Zn) concentrations ranged from 0.7940 mg/kg to 1.029 mg/kg, with a mean of 0.9115 ± 0.1662 mg/kg. Copper (Cu) levels varied between 0.4280 mg/kg and 0.7420 mg/kg, averaging 0.5850 ± 0.2220 mg/kg. Manganese (Mn) concentrations spanned from 0.2070 mg/kg to 0.3560 mg/kg, achieving a mean of 0.2815 ± 0.1054 mg/kg. Nickel (Ni) ranged from 0.1150 mg/kg to 0.1740 mg/kg, with a mean of 0.1445 ± 0.0417 mg/kg. Cobalt (Co) values fluctuated between 0.07300 mg/kg and 0.2130 mg/kg, yielding an average of 0.1430 ± 0.09899 mg/kg. Lead (Pb) concentrations varied from 0.02800 mg/kg to 0.03500 mg/kg, with a mean of 0.03150 ± 0.0049 mg/kg, while Cadmium (Cd) levels ranged from 0.01200 mg/kg to 0.01800 mg/kg, attaining an average of 0.01500 ± 0.0042 mg/kg. Iron (Fe) concentrations spanned from 1.279 mg/kg to 1.568 mg/kg, with a mean of 1.424 ± 0.2044 mg/kg.

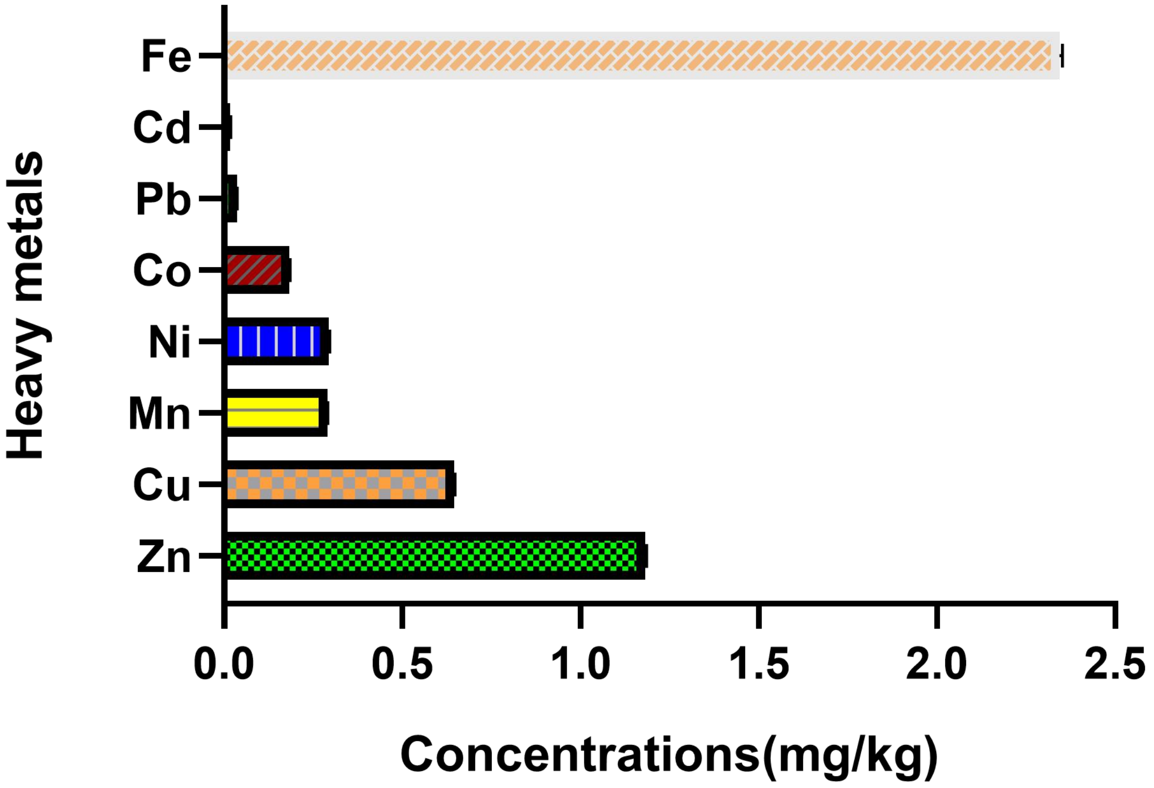

Fig 4.3.2 Heavy metal concentration in earthworm from industrial zone

CHAPTER FIVE

DISCUSSION

5.1. Site-Specific Contamination Patterns

Botanical Garden: A Low-Impact Site with Atmospheric Deposition

The botanical garden had the lowest recorded heavy metal concentrations in soil, with zinc (1.370 mg/kg) and cadmium (0.01750 mg/kg). This is likely due to limited industrial activity and regular site maintenance. However, despite the lower soil contamination, earthworms in this location accumulated significant amounts of iron (3.342 mg/kg) and cadmium (0.01450 mg/kg). This suggests potential atmospheric deposition from nearby urban sources, as airborne pollutants from vehicle emissions and industrial activities can settle onto soils. Similar findings have been reported in urban parks worldwide, where metals accumulate over time despite minimal direct contamination sources (Smith et al., 2020).

Automobile Workshop: Elevated Lead and Zinc Concentrations

The automobile workshop soil exhibited higher concentrations of zinc (1.661 mg/kg) and lead (0.02100 mg/kg). These elevated levels can be attributed to vehicular emissions, wear and tear of brake pads, used engine oil disposal, and battery waste. Although lead concentrations remained within regulatory limits, its presence raises concerns due to its neurotoxic effects. Interestingly, earthworms in this site showed lower metal bioaccumulation (e.g., zinc: 0.3600 mg/kg vs. soil zinc: 1.661 mg/kg). This discrepancy suggests potential avoidance behavior, physiological stress, or metal toxicity affecting uptake efficiency. Similar studies in Lagos mechanic workshops have reported reduced earthworm populations in lead-contaminated soils (Adeyemi et al., 2021).

Industrial Zone: High Cadmium Contamination

The industrial zone recorded the highest heavy metal contamination, with cadmium (0.2700 mg/kg) exceeding the World Health Organization (WHO) safety limit of 0.08 mg/kg for agricultural soils. Earthworms in this area also showed significant bioaccumulation of cadmium (0.01500 mg/kg) and lead (0.03150 mg/kg), reflecting the uncontrolled release of industrial waste, including electronic waste and metal residues. Cadmium, known for its carcinogenic properties, poses long-term ecological and human health risks. This aligns with findings from e-waste sites in Ghana, where cadmium contamination led to biodiversity loss and soil degradation (Asante et al., 2022).

5.2 Earthworms as Bioindicators of Soil Contamination

The bioaccumulation patterns observed in earthworms closely mirrored soil contamination trends across all three sites. Earthworms from the industrial zone accumulated the highest levels of cadmium and lead, reinforcing their role as effective bioindicators of heavy metal pollution. The lower metal uptake in the automobile workshop suggests that earthworms may exhibit avoidance mechanisms or suffer physiological impairment in highly polluted environments. These findings are consistent with studies indicating that earthworms accumulate metals through ingestion and dermal absorption, making them valuable for biomonitoring contaminated sites (Spurgeon and Hopkin, 1996).

5.3 Conclusion

This study highlights significant site-specific variations in heavy metal contamination in urban soils and earthworms in Benin City. The industrial zone emerged as the most contaminated, particularly due to cadmium accumulation, exceeding regulatory safety limits. The automobile workshop showed elevated lead and zinc concentrations, primarily from vehicular emissions and mechanical waste. Despite lower soil contamination in the botanical garden, earthworms exhibited notable bioaccumulation, suggesting atmospheric deposition as a contamination pathway.

Earthworm bioaccumulation trends confirmed their effectiveness as bioindicators, reflecting local pollution levels. Given the potential ecological and health risks associated with heavy metal exposure, this study underscores the need for stricter environmental regulations, improved waste management practices, and remediation efforts in highly polluted areas.

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APPENDIX

Figure 1 (Map Showing Study Area)