# EVALUATION OF HEAVY METALS (Pb, Cu, Fe and Mn) CONCENTRATION AND THE PHYSICOCHEMICAL PROPERTIES OF THE SOIL AT A SOLID WASTE DISPOSAL SITE IN OVIA NORTHEAST

BY

**OSAGIEDE OSASERE EFOSA**

**ENG1905039**

**DEPARTMENT OF CHEMICAL ENGINEERING**

**FACULTY OF ENGINEERING**

**UNIVERSITY OF BENIN**

**BENIN CITY**

**FEBRUARY, 2025**

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OSAGIEDE OSASERE EFOSA

BEING A PROJECT SUBMITTED TO THE DEPARTMENT OF CHEMICAL ENGINEERING, FACULTY OF ENGINEERING, UNIVERSITY OF BENIN, BENIN CITY

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF A BACHELOR'S DEGREE (B.ENG) IN CHEMICAL ENGINEERING

FEBRUARY, 2025

# CERTIFICATION

This is to certify that this research project was carried out by OSAGIEDE OSASERE EFOSA of the Department of Chemical Engineering at the University of Benin, Benin City, Edo State, Nigeria.

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| **ENGR MRS. EDOKPAYI**<br>PROJECT SUPERVISOR | **DATE** |
| **PROF. S.E. UWADIAE**<br>PROJECT COORDINATOR | **DATE** |
| **PROF. (MRS.) E.T. AKHIHEIRO**<br>HEAD OF DEPARTMENT | **DATE** |
| **EXTERNAL EXAMINER** | **DATE** |

# DEDICATION

I dedicate this project to God, whose constant guidance, wisdom, and blessings have shaped my academic path. To my family, friends, and mentors, your unwavering support and belief in me have been my greatest source of motivation. Thank you for encouraging me to strive for excellence.

# ACKNOWLEDGEMENT

I sincerely express my profound gratitude to my parents, Mr. Eguagie Osagiede and Mrs. Esther Osagiede for their support throughout this journey. I also want to appreciate my project supervisor, Engr. Mrs. Edokpayi for her corrections throughout my research project.

# TABLE OF CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

# ABSTRACT

With Nigeria generating over 42 million tonnes of waste annually, improper disposal poses significant risks to soil health, groundwater, and public health. This study examines the contamination levels of heavy metals and the physicochemical properties of soil at a solid waste disposal site in Ovia Northeast, Edo State, Nigeria. Soil samples were collected at varying depths (10, 20, 30, and 40 cm) from a dumpsite and a control site, focusing on lead (Pb), iron (Fe), copper (Cu), and manganese (Mn), alongside properties such as pH, bulk density, porosity, organic matter, and electrical conductivity (EC).

Results revealed elevated levels of heavy metals at the dumpsite compared to the control site, particularly in the top 10 cm of soil. For example, Pb concentrations reached 12.31 mg/kg at the dumpsite, nearly three times higher than the 4.24 mg/kg observed at the control. Similarly, copper (Cu) levels at the dumpsite peaked at 74.22 mg/kg, significantly higher than the control site's 57.47 mg/kg. Physicochemical properties demonstrated a strong influence on metal mobility: soil pH at the dumpsite ranged from 7.12 to 7.62, slightly higher than the control's 6.86 to 6.12. Organic matter content decreased with depth, from 8.74% at the surface to 3.15% at 40 cm in the dumpsite, compared to 9.07% to 2.54% in the control. EC values were markedly higher at the dumpsite (252–290 µS/cm) compared to the control (144–168 µS/cm), reflecting leachate infiltration and ion enrichment.

The findings underscore the environmental risks posed by heavy metal contamination, including soil degradation, reduced fertility, and potential bioaccumulation in the food chain. Elevated metal concentrations exceeded WHO permissible limits, necessitating immediate remediation actions. Recommendations include the implementation of sustainable waste management practices, soil remediation techniques such as phytoremediation, and ongoing monitoring to mitigate long-term environmental impacts.

# CHAPTER 1

# INTRODUCTION

## 1.1.BACKGROUND OF STUDY

Waste refers to materials that are broken, worn out, contaminated, or no longer useful due to spoilage. According to (Iorhemen et al., 2016; Salami et al., 2019), municipal solid waste refers to any undesired solid materials or substances human activity generates. Nigeria's waste generation rate is estimated to be 0.65-0.95 kg/capita/day, resulting in an average yearly garbage generation of 42 million tonnes. This represents more than half of the 62 million tonnes of waste created in Sub-Saharan Africa each year, making proper management and disposal a major issue with most of this waste ending up in an unregulated dump site.(Sam-Uroupa & Ogbeibu, 2020a).

Heavy metals such as lead (Pb), cadmium (Cd), chromium (Cr), and nickel (Ni) are persistent environmental pollutants, commonly associated with human activities like industrial processes and waste disposal. Dumpsites often act as significant sources of these metals as solid waste from industrial, domestic, and electronic sources degrade over time, releasing leachates rich in heavy metals into the surrounding soil. Research shows that the infiltration of water through waste material leads to the mobilization of metals, which migrate into the soil matrix. (Zhang et al., 2008) . Additionally, improper management of municipal solid waste accelerates this contamination process. Once in the soil, heavy metals can bind to organic matter or be absorbed by soil particles, leading to long-term accumulation in the environment. (Dehghani et al., 2021; Tenodi et al., 2020) . These toxins not only degrade soil fertility and structure but can also penetrate groundwater systems, extending their reach throughout ecosystems.

The health hazards posed by heavy metal pollution are well-documented. Exposure to these metals, either through direct contact with contaminated soil, ingestion of contaminated water, or consumption of crops grown in polluted soils, can lead to severe health issues such as cancer, kidney damage, neurological disorders, and developmental problems (Alengebawy et al., 2021). Heavy metals affect soil microorganisms in the environment, reducing biodiversity and disrupting ecological functions. Long-term, the accumulation of heavy metals can lead to bioaccumulation in the food chain, posing chronic health risks to both humans and animals. Studies emphasize that these contaminants can remain in the environment for decades, contributing to persistent environmental degradation (Järup, 2003). The long-term effects include reduced soil productivity, loss of vegetation, and irreversible changes to the natural ecosystem's balance.

Soil, the topmost layer of soil, is essential for plant growth and ecosystem health due to its high concentration of nutrients and organic materials. It acts as a reservoir for vital nutrients such as nitrogen, phosphorus, and potassium, which are required for plant growth. (Weil & Brady, 2017). Soil is often the focus of environmental studies because it regulates water retention, provides habitat for microorganisms, and promotes carbon sequestration, all of which are critical for ecosystem sustainability. Furthermore, soil health is directly related to agricultural output since it delivers nutrients to crops and maintains root structures, making it critical for food security and ecosystem services. (Demas & Rabenhorst, 2001).

Soil physicochemical characteristics such as pH, electrical conductivity, bulk density, and porosity substantially impact heavy metal mobility and bioavailability. Soil pH, for example, regulates metal solubility; lower pH (acidic conditions) increases metal solubility, making it more mobile and accessible. (Draszawka-Bołzan, 2015) . Electrical conductivity indicates the existence of salts, which can influence metal mobility via competitive ion exchange processes. Organic matter can bind to heavy metals, limiting their bioavailability and potentially boosting long-term soil accumulation. These factors affect not just how metals migrate through the soil, but also how they damage water bodies through leaching and entering the food chain through plant or animal intake.(Pérez-de-Mora et al., 2007).

Evaluating heavy metal pollution and soil qualities at Nigerian dumpsites, such as Ovia Northeast, is critical for assessing environmental concerns, developing mitigation methods, and protecting human health from long-term exposure to hazardous metals. The aim of the study therefore is to evaluate heavy metals (Pb, Fe, Cu, and Mn) Contamination and the physicochemical properties of the soil at a solid waste disposal site in Ovia Northeast.

## 1.2 STATEMENT OF PROBLEM

Ovia Northeast, located in Edo State, Nigeria, is a combination of urban, semi-urban, and rural communities, with agriculture being a prominent economic. The environment supports rapid vegetation development, but the terrain and soil composition make the area prone to erosion and runoff, particularly during the rainy season. (Onaiwu, 2021) . These conditions, combined with rapid urbanization increase the region's exposure to pollution, especially in areas near poorly managed solid waste disposal sites leading to environmental degradation.

Rapid urbanization and population growth have overwhelmed existing waste management systems in Ovia Northeast, leading to open dumpsites where waste is indiscriminately disposed of without adequate segregation or treatment.(Ike et al., 2018). These dumpsites usually contain a mixture of residential, industrial, and electronic trash, all of which contribute to the discharge of dangerous compounds into the soil, such as heavy metals. Studies reveal that leachate from these dumpsites can penetrate adjacent soils and water bodies, posing environmental and health problems. (Afolabi & Eludoyin, 2021) . In some instances, increased levels of pollutants have been detected in nearby water sources, posing long-term threats to both human populations and local ecosystems. Addressing these risks is crucial for the sustainable development of the region and the protection of public health and evaluating the heavy metal levels and physicochemical properties of the soil is a step in the right direction.

## 1.3 AIM AND OBJECTIVES

The study aims to evaluate the presence of certain heavy metals (Pb, Fe, Cu, and Mn) and the physicochemical properties of the soil at a solid waste disposal site in Ovia Northeast.

The following objectives would be followed to achieve the aim:

1. To determine the levels of lead (Pb), iron (Fe), copper (Cu), and manganese (Mn) in the soil samples collected and compare them to established safety limits.
2. To evaluate the physicochemical properties of the soil, including pH, electrical conductivity, organic matter content, bulk density, and porosity.
3. To investigate the correlation between the concentration of heavy metals and various soil physicochemical properties.
4. To assess the potential impact of leachate from the solid waste disposal site on the surrounding soil and groundwater quality, focusing on how it contributes to heavy metal contamination.
5. To develop recommendations for effective waste management practices and soil remediation strategies aimed at reducing heavy metal contamination in the study area.

## 1.4. SCOPE OF STUDY

The study will focus on the evaluation of heavy metal contamination in the soil at the solid waste disposal site in Oluku, Ovia Northeast, Edo State, Nigeria. The research will encompass:

1. The study will be limited to the Oluku dump site and a control site located over 1000 meters away from the contaminated area.
2. Soil samples will be collected at varying depths (10, 20, 30, and 40 cm) to assess how depth influences heavy metal concentrations and soil physicochemical properties.
3. The research will specifically target lead (Pb), iron (Fe), copper (Cu), and manganese (Mn) as the key heavy metals of concern due to their prevalence in municipal solid waste and associated health risks.
4. The study will employ standard laboratory techniques for analyzing heavy metal concentrations and assessing the physicochemical properties of the soil samples.
5. The analysis will focus on data collected during the sampling period, with an emphasis on understanding the current state of soil contamination and properties, as well as potential long-term implications for local ecosystems and public health.

## 1.5. RELEVANCE OF STUDY

The study's findings have the potential to dramatically impact waste disposal procedures by detecting the level of heavy metal contamination and emphasizing the significance of soil physicochemical characteristics in regulating metal mobility and bioavailability. Understanding these processes allows for more targeted and effective soil remediation measures, which reduces the long-term environmental and health dangers posed by dumpsites.

The study's findings could help inform policymaking in Nigeria by giving data to promote stronger waste management and environmental monitoring legislation. Such laws may result in improved waste segregation, better landfill management, and the adoption of sustainable practices, ultimately protecting ecosystems and public health in Nigeria and other areas facing comparable environmental difficulties.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1. POLLUTION

Pollution— i.e., unwanted waste of human origin released to air, land, water, and the ocean without regard for cost or consequence—is an existential threat to human health and planetary health, and jeopardizes the sustainability of modern societies. Pollution includes contamination of air by fine particulate matter ($PM_{2\cdot5}$); ozone; oxides of sulfur and nitrogen; freshwater pollution; contamination of the ocean by mercury, nitrogen, phosphorus, plastic, and petroleum waste; and poisoning of the land by lead, mercury, pesticides, industrial chemicals, electronic waste, and radioactive waste. (Fuller et al., 2022).

Pollution, also called environmental pollution, is the addition of any substance (solid, liquid, or gas) or any form of energy (such as heat, sound, or radioactivity) to the environment at a rate faster than it can be dispersed, diluted, decomposed, recycled, or stored in some harmless form. The major kinds of pollution, usually classified by environment, are air pollution, water pollution, and land pollution.

### 2.1.1. Air Pollution

One of the major contributors to air pollution is industrialization, although it can't be eliminated; yet, it can be significantly reduced. When gases, dust particles, smoke, or odors are introduced into the atmosphere in a way that is hazardous to the environment, it is said to be polluting the air. Air pollution poses a significant threat to the health of people and other species in the environment. It creates smog and acid rain, causes cancer and respiratory diseases, reduces the ozone layer atmosphere, and contributes to global warming.

Air pollution can result from both human and natural actions. Natural events that pollute the air include forest fires, volcanic eruptions, wind erosion, pollen dispersal, evaporation of organic compounds, and natural radioactivity. Sources of air pollution refer to the various locations, activities, or factors that are responsible for the release of pollutants into the atmosphere.

Carbon dioxide emissions into the atmosphere are one of the main sources of air pollution. Deforestation and fossil fuel combustion also play a role. Another significant source of air pollution, sulfur dioxide is produced when sulfur-containing fossil fuel components are burned and discharged into the atmosphere. When sulfate levels are high, it is particularly dangerous to human health and it also contributes to acid rain. Through the stratospheric ozone layer's reduction, chlorofluorocarbons also contribute to air pollution. (Pratap Choudhary et al., 2013).

### 2.1.2. Water Pollution

If certain elements or conditions are present to the extent that the water cannot be used for a certain purpose, the water is said to be polluted. (FW Owa, 2023). According to (FW Owa, 2023) Water pollution is the presence of an unsafe substance (pollutants) in large enough quantities to make the water unfit for drinking, bathing, cooking, or other purposes. Humans generally induce water pollution. The growth of the human population and industrial and agricultural practices are the major causes of pollution. (Eguabor V., 1998).

According to (SPT Gbamanja, 1998), Water pollution in Nigeria results from a variety of activities. Some of these activities include;

Water pollution in Nigeria stems from a variety of sources and factors, including:

i. Sewage leakages
ii. High population density

iii. Oil spillage

iv. Disposal of industrial waste into water bodies

v. Pollution of groundwater due to drilling activities

vi. Flooding during the rainy season, which carries waste into waterways

vii. Construction of lavatories and visionaries near water bodies, common in riverine areas

viii. Radioisotope contamination

ix. Heavy metal pollution

x. Combustion-related emissions

xi. Improper disposal of toxic waste at sea

xii. Activities like mineral processing, such as coal production

xiii. Erosion-induced sediment runoff

xiv. Deforestation

xv. Mining operations

xvi. Littering in water environments

xvii. The use of pesticides

xviii. Herbicides and fertilizers in agriculture

xix. Failing septic systems

xx. Household chemical discharges

xxi. Animal waste contamination.

These diverse factors collectively contribute to the significant challenges of water pollution in Nigeria, necessitating comprehensive measures for prevention and mitigation.

### 2.1.3. Land Pollution

Land pollution refers to the introduction of large quantities of harmful materials into a given land area, which may be distinguished into various types including; invasive, non-invasive, industrial, commercial, and domestic land pollution respectively.

Land pollution is the act, process, and condition of severe contamination on and below the surface of the Earth as a result of any of various causes, such as deforestation and urbanization, inefficient resource handling (including energy resource mining, raw material extraction, oil spill), unsustainable agriculture, waste mismanagement, and unsustainable manufacturing, to name a few. (Ofoezie et al., 2022). It is important to note that the beneath-surface impact of land pollution only happens when highly mobile contaminants migrate vertically from the surface under the pull of gravity.

#### 2.1.3.1. Soil Pollution

Soil pollution, a significant environmental issue, involves the contamination of soil with toxic substances, heavy metals, and chemicals. The origins of these pollutants range from industrial operations to agricultural practices and improper waste disposal. Contaminants in the soil can affect its fertility, disrupt ecosystems, and have harmful effects on human health by infiltrating food chains and groundwater systems. According to (KUMAR Mishra & Roychoudhury, 2016), soil pollution leads to a reduction in soil quality and long-term agricultural productivity, threatening food security and biodiversity.

Waste dump sites are among the largest contributors to soil pollution. These sites often serve as disposal grounds for various types of waste, including municipal, industrial, and hazardous waste. Leachate, the liquid generated from waste decomposition, often contains toxic chemicals like heavy metals—lead (Pb), cadmium (Cd), chromium (Cr), and nickel (Ni)—that seep into the soil.

Studies by(Biose et al., 2021a, 2021b; Karim et al., 2017) indicate that leachate from waste dump sites can cause elevated levels of heavy metals in surrounding soils, which persist for long periods, disrupting the ecosystem and entering the human food chain.

Moreover, the presence of waste dump sites significantly alters the physicochemical properties of the soil. These changes can include alterations in soil pH, nutrient availability, and electrical conductivity, leading to less favorable conditions for plant growth. Furthermore, organic waste decomposition contributes to methane emissions, exacerbating climate change. (Siddiqua et al., 2022) Highlight that these environmental impacts stress the need for sustainable waste management strategies and soil remediation efforts to mitigate the adverse effects on soil quality and human health.

## 2.2. POLLUTANTS

Pollutants are substances introduced into the environment that cause harm or adverse changes to ecosystems, human health, and the atmosphere. These pollutants can take many forms, such as chemicals, heavy metals, plastics, and even biological agents. They can be emitted by natural processes, such as volcanic eruptions, but are predominantly the result of human activities like industrial manufacturing, transportation, agriculture, and waste disposal. Pollutants have long-term effects, as they can accumulate in the environment, leading to chronic health issues and environmental degradation. According to (Duarte et al., 2018; Shetty et al., 2023), human-made pollutants, particularly chemicals, play a significant role in environmental pollution and its subsequent effects on air, water, and soil quality.

Among the various types of pollution, soil pollution has become a major concern, especially due to its long-lasting impact on agricultural productivity and human health. Soil pollutants are introduced into the soil through several pathways, including agricultural activities (like excessive pesticide and fertilizer use), industrial waste disposal, improper waste management, and mining. These pollutants can alter the natural composition of the soil, leading to a reduction in soil fertility, which affects plant growth and food production. Additionally, soil pollutants can leach into groundwater, contaminating drinking water supplies and leading to a wide range of health issues in local communities (Biose et al., 2021c; Sam-Uroupa & Ogbeibu, 2020b). Heavy metals, persistent organic pollutants (POPs), and agrochemicals are among the most common pollutants found in contaminated soils.

### 2.2.1. Heavy metals

Heavy metals are a group of metallic elements with high atomic weights and densities that are toxic at low concentrations. Common heavy metals include lead (Pb), cadmium (Cd), mercury (Hg), arsenic (As), chromium (Cr), and nickel (Ni). These metals can originate from various anthropogenic activities, such as industrial processes, mining, agricultural practices, and improper waste disposal. Due to their persistence in the environment and tendency to bioaccumulate in living organisms, heavy metals pose significant risks to human health and ecological systems. For instance, exposure to lead can lead to neurological impairment, particularly in children, while cadmium is known to cause kidney damage and bone fragility. (Alloway, 2013; Järup, 2003).

Heavy metal pollution in soil is particularly concerning as it can affect agricultural productivity and food safety. Contaminated soils can lead to reduced crop yields and impaired plant growth due to the toxic effects of heavy metals on root development and nutrient uptake. Furthermore, these metals can accumulate in the edible parts of plants, leading to human exposure through the food chain. According to a study by Weng et al. (2018), soil contaminated with heavy metals can significantly affect the health of local populations, as dietary intake is a primary route of exposure. This is particularly alarming in areas where subsistence farming occurs, as communities relying on locally grown food may face increased health risks.

The remediation of heavy metal-contaminated soils is a complex challenge due to the metals' chemical stability and tendency to bind with soil particles, making them difficult to remove. Various methods, such as phytoremediation, soil washing, and the use of immobilizing agents, are being explored to address this issue. Phytoremediation, for example, utilizes plants to absorb and concentrate heavy metals from the soil, making them a promising and environmentally friendly solution for soil decontamination. (Jõul et al., 2018). However, the effectiveness of these methods depends on factors such as soil type, metal concentration, and plant species used, necessitating further research to optimize remediation strategies.

## 2.3. PHYSICOCHEMICAL PROPERTIES OF SOIL

Soil, the uppermost layer of soil, plays a critical role in supporting plant growth, maintaining ecological balance, and regulating water cycles. Typically, soil is rich in organic matter, nutrients, and microorganisms, making it vital for agricultural productivity and environmental health. It generally extends to a depth of about 5 to 20 centimeters, depending on the geographic location and climatic conditions. The physicochemical properties of soil influence its capacity to retain moisture, provide essential nutrients to plants, and support a diverse range of organisms. Understanding these properties is crucial for effective soil management, conservation, and sustainable agricultural practices.

### 2.3.1. pH

Soil pH is a crucial physicochemical property in soil pollution studies, as it significantly influences the chemical form, mobility, and bioavailability of pollutants, particularly heavy metals. A lower pH, indicating acidic conditions, typically increases the solubility of metals, making them more mobile and bioavailable, thereby enhancing the risk of environmental contamination and uptake by plants. Conversely, higher pH (alkaline conditions) tends to reduce metal solubility, leading to greater adsorption onto soil particles and reduced mobility. This interaction is vital in evaluating pollution risks, especially in waste disposal sites where leaching of toxic metals could occur. Studies by (Neina, 2019) demonstrate that soil pH plays a pivotal role in controlling the retention or release of heavy metals, thus affecting contamination spread. Likewise, research by (Kicińska et al., 2022) highlights that soil pH not only determines the speciation of pollutants but also their toxicity, making it a key parameter in soil pollution management.

### 2.3.2. Soil Porosity

Soil porosity, or the volume of pores or voids in the soil, is an important physicochemical parameter for assessing soil contamination because it affects the flow and retention of pollutants, water, and air within the soil matrix. High porosity often allows water and pollutants to infiltrate and percolate through soil layers, potentially reaching groundwater. Low porosity, on the other hand, might restrict movement, potentially resulting in pollutant accumulation in surface soils. This dynamic is critical in managing pollution in agricultural and waste disposal sites, as contaminants like heavy metals can be held in surface layers or leach into deeper strata depending on porosity.

(Huang et al., 2020) found that soil porosity impacts heavy metal mobility, emphasizing the importance of exact characterization in predicting contamination hazards. Similarly, (Keesstra et al., 2012) found that changes in soil structure, notably porosity, affect the soil's ability to filter contaminants, which influences environmental risk assessments at polluted areas.

### 2.3.3. Organic Matter

Organic matter, primarily derived from decomposed plant and animal materials, improves soil structure, enhances nutrient retention, and promotes moisture-holding capacity. A higher organic matter content typically leads to increased microbial activity, which contributes to nutrient cycling and the formation of humus. According to Wang et al. (2018), soils with higher organic matter levels can retain moisture more effectively, reducing the need for irrigation and enhancing drought resilience.

### 2.3.4. Bulk Density

Bulk density, the mass of soil per unit volume, is a critical physicochemical property affecting soil pollution dynamics, as it influences soil compaction, porosity, and permeability. High bulk density typically indicates compacted soils with lower porosity, which can reduce water infiltration and limit the movement of air and pollutants. This can lead to the accumulation of contaminants near the surface, posing a risk of pollution, especially in areas affected by industrial waste (Korchagina et al., 2014) . Low bulk density, on the other hand, often corresponds to more porous soils, allowing for greater pollutant infiltration and migration. (Chen et al., 2021) demonstrates that bulk density impacts the retention of heavy metals, with higher-density soils showing limited pollutant transport.

### 2.3.5. Cation Exchange Capacity (CEC)

Cation exchange capacity (CEC) refers to the soil's ability to retain and exchange positively charged ions (cations), such as calcium, magnesium, potassium, and sodium. Higher CEC values indicate better nutrient-holding capacity, allowing the soil to supply essential nutrients to plants over time. Soils with low CEC may require more frequent fertilization to meet crop nutrient needs (Havlin et al., 2014). CEC is influenced by soil texture and organic matter content, making it an important factor in soil fertility management.

### 2.3.6. Soil Texture

Soil texture, which describes the relative proportions of sand, silt, and clay particles, significantly affects water retention, aeration, and nutrient availability. Sandy soils, for example, drain quickly and have lower nutrient-holding capacities, while clayey soils tend to retain water but may become compacted, restricting root growth. Loamy soils, a balanced mix of sand, silt, and clay, are often considered ideal for agriculture due to their ability to retain moisture while providing good drainage and aeration (Tisdall & Oades, 1982). Understanding soil texture is crucial for selecting appropriate crops and determining the necessary management practices.

### 2.3.7. Soil Electrical conductivity (EC)

Soil electrical conductivity (EC) is a key physicochemical property in assessing soil pollution, as it serves as an indicator of the concentration of soluble salts in the soil. Elevated EC levels often correlate with higher concentrations of contaminants such as heavy metals and salts, which can inhibit plant growth and alter soil microbial activity (Butnariu, 2015; Weissmannová & Pavlovský, 2017). EC is particularly important in evaluating pollution in agricultural and waste disposal sites, as it can indicate the extent of salinization or contamination by industrial effluents.

High EC can affect the mobility of ions and pollutants in the soil solution, making it a useful parameter for monitoring soil degradation. EC is a sensitive indicator of soil contamination and helps in understanding the distribution of pollutants in various soil layers. (Singh & Dhumal, 2019) highlight how EC affects the solubility and mobility of heavy metals, which in turn influences the potential for environmental harm.

### 2.3.8. Moisture Content

Moisture content is a vital property of soil, influencing plant growth and soil biota. The moisture-holding capacity of soil depends on its texture, structure, and organic matter content. Proper moisture management is essential for maintaining optimal growing conditions for crops. Techniques such as mulching, cover cropping, and conservation tillage can help improve moisture retention in soil, enhancing agricultural sustainability (Morris et al., 2018).

# CHAPTER 3

# MATERIALS AND METHODS

## 3.1 STUDY AREA

The study area is Oluku in Ovia Northeast Local Government Area (LGA) in Edo State, Nigeria, which lies approximately between the Latitude: 6.4° N to 6.8° N and Longitude: 5.4° E to 5.7° E (Figure 3.1) and is part of the humid tropical region characterized by high rainfall and rich biodiversity. Ovia Northeast has an annual average rainfall of approximately 2,000 mm to 2,500 mm and an average annual temperature range of 25°C to 30°C. The dump field investigated is located in Oluku along Benin-Lagos Road lying between Latitude: 6.4067° N and Longitude: 5.6009° E.

Figure 3. 1: Map of the Study area

## 3.2. SAMPLE COLLECTION

Soil samples were collected using a standard soil auger at varying depths (10, 20, 30, and 40 cm) from the designated dump site and a control station located over 1000 meters away from the contaminated area. The sampling was conducted in September 2024, during the first month of the sampling period. Four soil samples were collected for the site and the control, yielding eight samples. All samples were carefully labeled and stored in polythene bags to prevent contamination and preserve the integrity of the samples for subsequent analysis.

## 3.3. SAMPLE PREPARATION

The soil samples underwent a series of preparation steps to ensure accuracy and consistency in subsequent heavy metal analysis. Eight soil samples, comprising four from varying depths at the contaminated site and four from the control site, were processed. Each sample was prepared in triplicate to enhance the reliability and reproducibility of results.

The samples were initially air-dried at room temperature to remove residual moisture. This process continued until the soil reached a constant weight, ensuring thorough drying without altering the chemical composition of the metals present. Once dried, the samples were ground using a mechanical mortar and pestle to break down aggregates and achieve a fine, homogeneous powder. This step minimized variability between replicates and ensured even distribution of metal contaminants.

The ground soil was passed through a 2 mm mesh sieve to remove larger particles, stones, and organic debris. The fine, sieved fraction was collected for further preparation. To ensure uniformity, the sieved soil was thoroughly mixed, preventing localized variations in metal concentrations.

For digestion, approximately 1 g of each sieved and homogenized sample was accurately weighed using a weighing balance. This process was repeated three times per sample, resulting in triplicate preparations. The triplicate measurements allowed for the detection of any discrepancies and improved the statistical significance of the analysis.

To prevent cross-contamination, all equipment, including the mortar, pestle, and sieve, was meticulously cleaned with deionized water and acid-washed between samples. The prepared samples were labeled and stored in airtight containers until digestion. This storage step ensured that the samples remained uncontaminated and preserved their integrity prior to the aqua regia digestion and subsequent Atomic Absorption Spectroscopy (AAS) analysis.

## 3.4. MATERIALS AND REAGENTS USED

The following materials and apparatuses were used for the experiment of this study.

### 3.4.1. Apparatus Used

Table 3. 1: Apparatus and Reagents Used for Physicochemical and Heavy Metal Analysis

| S/N | Apparatus/Reagents | Source | Uses |
|---|---|---|---|
| 1 | pH Meter | Laboratory Supply | Measures the pH of soil samples |
| 2 | Standard Buffer Solutions (pH 4.0, 7.0) | Analytical Reagents | Calibrates the pH meter |
| 3 | Weighing Balance | Laboratory Supply | Accurately measures the mass of soil samples |
| 4 | Mechanical Mortar and Pestle | Laboratory Supply | Grinds soil samples to a fine powder |
| 5 | 2 mm Sieve | Laboratory Supply | Sieves soil to remove large particles |
| 6 | Bulk Density Apparatus | Laboratory Supply | Collects undisturbed soil samples |

| | | | |
|---|---|---|---|
| | (Metal Core) | | for bulk density |
| 7 | Graduated Cylinder | Laboratory Supply | Measures volume for porosity calculations |
| 8 | Electrical Conductivity Meter | Laboratory Supply | Measures the electrical conductivity of soil samples |
| 9 | Desiccator | Laboratory Supply | Preserves dried soil samples to prevent moisture |
| 10 | Aqua Regia ($HNO_3$ : $HCl$, 3:1) | Analytical Reagents | Digests soil samples for heavy metal extraction |
| 11 | Atomic Absorption Spectrometer | Analytical Equipment (AAS Lab) | Analyzes heavy metal concentrations in digested soil |
| 12 | Deionized Water | Laboratory Supply | Used for rinsing equipment and diluting samples |
| 13 | Organic Matter Testing Kit | Laboratory Supply | Measures the organic matter content in soil |
| 14 | Beakers | Laboratory Supply | Holds and mixes solutions during digestion |
| 15 | Pipettes and Burettes | Laboratory Supply | Transfers and measures liquids accurately |
| 16 | Funnel | Laboratory Supply | Aids in filtration and transferring |

| | | | |
|---|---|---|---|
| | | | liquids |
| 17 | Filter Paper | Laboratory Supply | Filters digested samples before AAS analysis |
| 18 | Conical Flask | Laboratory Supply | Holds soil digest solutions during analysis |
| 19 | Shaker Machine | Laboratory Supply | Agitates soil-to-water mixtures for pH and EC tests |

## 3.6. SAMPLE ANALYSIS

### 3.6.1. Analysis of Heavy Metals

The determination of heavy metal content in the soil samples was carried out using aqua regia digestion followed by analysis with Atomic Absorption Spectroscopy (AAS) (Lee et al., 2018). Aqua regia digestion, a standard and effective method for metal extraction from complex soil matrices, was employed due to its ability to dissolve a wide range of metals, including those bound in silicate and sulfide phases. This method utilizes a mixture of concentrated nitric acid ($HNO_3$) and hydrochloric acid (HCl) in a 3:1 volumetric ratio, facilitating the breakdown of organic matter and the release of bound metals into solution.

For the digestion process according to studies by (Osibanjo et al., 2021; Tüzen, 2003) , approximately 1 g of each soil sample was accurately weighed and transferred to digestion vessels. A volume of aqua regia, typically consisting of 9 mL of HCl and 3 mL of $HNO_3$ (3:1), was added to each vessel, ensuring complete coverage of the sample. The vessels were placed on a hot plate and heated at 95°C for a period of 1 to 2 hours. Care was taken to avoid boiling, allowing the mixture to reflux gently, thereby enhancing the dissolution of metals. The digestion continued until a clear solution was obtained, indicating that most organic and mineral components had been dissolved. After cooling, the digestate was filtered using Whatman No. 42 filter paper to remove any residual particulates that could interfere with subsequent analysis. The filtrate was quantitatively transferred to a volumetric flask and diluted to 50 mL with deionized water, ensuring the consistency of results across all samples.

The digested samples were analyzed for lead (Pb), cadmium (Cd), chromium (Cr), and nickel (Ni) using Atomic Absorption Spectroscopy (AAS) at the Geology Department of the University of Benin. AAS was chosen for its high sensitivity and specificity in detecting trace metal concentrations in environmental samples. Calibration of the AAS instrument was performed using certified standard solutions of each target metal to establish accurate calibration curves. The samples were aspirated into the flame, and the absorbance of each metal was measured at its characteristic wavelength.

To ensure reliability and precision the samples were analyzed in triplicates. For quality assurance and control, procedural blanks and standard reference materials were included in the analysis, and spiked recovery tests were conducted to assess the accuracy of the digestion and analysis process. Any deviations from expected recoveries were carefully noted and adjustments were made to ensure the validity of the results.

### 3.6.2. Analysis of Physicochemical Properties

#### 3.6.2.1. pH Analysis

To determine the pH of the soil samples, a soil-to-water suspension was prepared using a 1:2.5 ratio, where 10 g of soil was mixed with 25 mL of deionized water in a clean beaker. The mixture was stirred thoroughly and left to stand for 30 minutes to allow adequate suspension of the soil particles. The pH was then measured using a calibrated digital pH meter, ensuring that the electrode was immersed in the supernatant solution. Prior to the analysis, the pH meter was calibrated using standard buffer solutions of pH 4.0 and 7.0 to ensure accurate readings. The final pH value was recorded once the meter stabilized, providing a measure of the soil's acidity or alkalinity, which is crucial for understanding its suitability for various crops and microbial activity.

Soil pH is an essential parameter as it affects nutrient availability, microbial diversity, and overall soil health. Acidic soils (low pH) may hinder the availability of essential nutrients like phosphorus, while alkaline soils (high pH) may limit micronutrients like iron and zinc. For more detailed analysis, the pH meter used was calibrated before every set of measurements to ensure precision, minimizing errors in readings.

#### 3.6.2.2. Bulk Density (BD) Measurement

Bulk density was determined using the core method, which involves collecting undisturbed soil samples with a metal core sampler. A metal cylinder with a known volume (typically 100 $cm^3$) was pressed into the soil to collect a soil sample without disturbing its natural structure. The sample was carefully removed and weighed in its wet state. Afterward, the soil sample was air-dried. Once dried, the sample was weighed again, and the bulk density was calculated using the following formula:

$$Bulk\ Desnsity\ (BD) = \frac{\text{Dry Mass of Soil (g)}}{\text{Volume of Soil (cm}^3\text{)}} \qquad \text{...(3.1)}$$

This method gives an understanding of the compactness of the soil, which is crucial for water infiltration, root growth, and air circulation. Higher bulk density values are indicative of compacted soils that may restrict root development and water movement, leading to poor soil health. The results provide valuable information for assessing the soil's suitability for various agricultural practices.

### 3.6.2.3. Porosity Determination

The porosity of the soil samples was determined based on the relationship between the bulk density and particle density. Particle density was assumed to be 2.65 g/cm³, which is the standard value for mineral soils. Using the bulk density value obtained from the previous test, the porosity of the soil was calculated using the formula:

$$\text{Porosity (\%)} = \left(1 - \frac{\text{Bulk Density (g/}cm^3\text{)}}{\text{Particle Density (g/}cm^3\text{)}}\right) \times 100 \qquad \text{...(3.2)}$$

This formula calculates the percentage of the soil volume that is pore space, which is crucial for water retention and aeration. Porosity plays an important role in determining how much water the soil can hold, how easily air can reach plant roots, and how well water drains. Higher porosity generally suggests better soil structure and increased fertility, as it allows for better root growth and microbial activity (Danielson & Sutherland, 2018).

### 3.6.2.4. Electrical Conductivity (EC) Measurement

Electrical conductivity was determined using a conductivity meter after preparing a 1:5 soil-to-water extract. In this method, 10 g of soil was mixed with 50 mL of deionized water in a clean beaker. The mixture was thoroughly stirred for about 10 minutes to ensure the dissolution of soluble salts. Afterward, the solution was filtered to remove solid particles, and the electrical conductivity of the filtrate was measured using a conductivity meter. The meter was calibrated with standard solutions of known conductivity before measurement to ensure accuracy.

EC is an important indicator of the solubility of salts in the soil and provides insight into the soil's salinity level. High EC values may indicate soil salinization, which can negatively affect plant growth by limiting water uptake. By measuring the EC, it is possible to assess soil suitability for agricultural purposes, as high levels of dissolved salts can harm crops and reduce overall soil fertility. This test provides essential information for effective soil management, especially in areas prone to salinity problems.

#### 3.6.2.5. Organic Matter Analysis

The organic matter content of the soil samples was determined using the Walkley-Black wet oxidation method, a widely used technique for estimating soil organic matter. This method is based on the oxidation of organic matter by potassium dichromate ($K_2Cr_2O_7$) in the presence of concentrated sulfuric acid ($H_2SO_4$), followed by titration to quantify the unreacted dichromate.

To begin, approximately 1.0 g of air-dried, sieved (<2 mm) soil sample was accurately weighed and transferred into a clean, dry conical flask. Then, 10 mL of 1N potassium dichromate ($K_2Cr_2O_7$) solution was added to the soil sample, followed by 20 mL of concentrated sulfuric acid ($H_2SO_4$). The flask was gently swirled to ensure thorough mixing and allowed to stand for 30 minutes to enable complete oxidation of organic matter.

After the reaction period, 200 mL of distilled water was added to dilute the mixture. To determine the amount of unreacted dichromate, 10 mL of phosphoric acid ($H_3PO_4$) and 1 mL of diphenylamine indicator were added. The solution was then titrated with standardized 0.5N ferrous sulfate ($FeSO_4$) solution until the color changed from bluish-green to a distinct endpoint (dark green to reddish-brown).

The percentage of organic matter in the soil was calculated using the formula:

$$Organic\ Matter\ (\%) = \frac{(\mathrm{B} - \mathrm{S}) \times \mathrm{N} \times 0.003 \times 1.724 \times 100}{\text{Weight of Soil (g)}} \quad \text{... (3.3)}$$

Where:

- **B** = Volume (mL) of $FeSO_4$ used in the blank titration
- **S** = Volume (mL) of $FeSO_4$ used for the sample
- **N** = Normality of $FeSO_4$ solution
- **0.003** = Conversion factor for carbon
- **1.724** = Conversion factor from organic carbon to organic matter

# CHAPTER 4

# RESULTS AND DISCUSSION

In this chapter, the results of heavy metal analysis and physicochemical properties of soil at the solid waste disposal site are presented and interpreted. Data from different depths are compared with control samples to assess contamination levels. Trends in the distribution of lead (Pb), cadmium (Cd), chromium (Cr), and nickel (Ni) are discussed, with findings analyzed in relation to existing literature. This chapter aims to highlight the impact of waste disposal on soil quality and contribute to understanding contamination patterns.

## 4.1 PHYSICOCHEMICAL PROPERTIES OF SOIL SAMPLES

Physicochemical properties are crucial in soil analysis as they influence soil health, contamination levels, and overall environmental quality.

Tables 4.1 and 4.2 below present the physicochemical properties of soil samples from the dumpsite and control, respectively.

Table 4. 1: Physicochemical Properties of Dumpsite Soil Samples

| **Depth (cm)** | **pH** | **Bulk Density (BD) ($kg/m^3$)** | **Porosity (%)** | **Electrical Conductivity (EC) (µS/cm)** | **Organic Matter (%)** |
|---|---|---|---|---|---|
| 10 | 7.12 | 1180.17 | 56 | 252 | 8.740 |
| 20 | 7.22 | 1210.87 | 52 | 264 | 7.214 |
| 30 | 7.48 | 1225.68 | 46 | 262 | 5.060 |
| 40 | 7.62 | 1247.12 | 44 | 290 | 3.146 |

Table 4. 2: Physicochemical Properties of Control Soil Samples

| **Depth (cm)** | **pH** | **Bulk Density (BD) (kg/m³)** | **Porosity (%)** | **Electrical Conductivity (EC) (µS/cm)** | **Organic Matter (%)** |
|---|---|---|---|---|---|
| 10 | 6.86 | 1342.21 | 40 | 168 | 9.065 |
| 20 | 6.64 | 1313.50 | 44 | 194 | 9.700 |
| 30 | 6.43 | 1300.08 | 48 | 158 | 4.122 |
| 40 | 6.12 | 1235.50 | 52 | 144 | 2.540 |

The physicochemical properties of the dumpsite soil samples show notable trends across different depths. pH levels slightly increase with depth, from 7.12 at 10 cm to 7.62 at 40 cm, suggesting lower acidity at deeper layers. In contrast, the control samples show a decrease in pH with depth, indicating higher acidity (6.86 to 6.12). Bulk density (BD) in the dumpsite increases with depth, peaking at 1247.12 kg/m³ at 40 cm, while porosity decreases, suggesting compaction. The control site shows higher bulk density at the surface (1342.21 kg/m³), decreasing with depth and increasing porosity, indicating better structure and less compaction. Electrical conductivity (EC) is higher in dumpsite soil, peaking at 290 µS/cm at 40 cm, compared to 194 µS/cm at 20 cm for the control, indicating elevated ion concentration and possible leachate infiltration. Organic matter decreases with depth at the dumpsite (from 8.74% to 3.146%), mirroring the control, but with consistently lower values at deeper layers.

These findings align with previous studies highlighting the impact of waste disposal on soil properties (Akinro, 2014) . The dumpsite's higher pH and EC values reflect contamination and potential soil degradation. Elevated bulk density and reduced porosity can hinder root penetration and water retention, reducing agricultural productivity. Conversely, the control site's decreasing bulk density and higher porosity with depth indicate healthier soil with greater fertility potential. The depletion of organic matter at both sites signals declining nutrient availability, but the dumpsite's accelerated decline suggests faster degradation processes. These findings emphasize the need for soil remediation strategies to restore fertility and mitigate contamination risks, ensuring sustainable land use.

### 4.1.1 Relationship Between Depth and pH

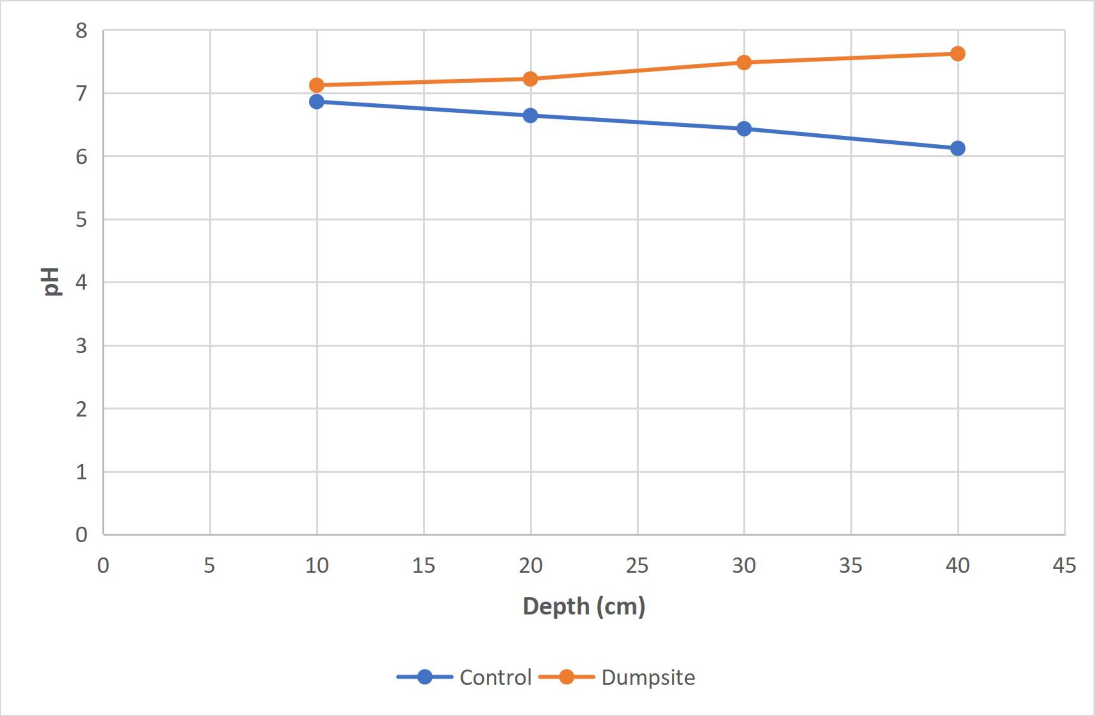

Figure 4. 1: Graph showing the relationship between Depth and pH

Figure 4.1 shows the pH values at different depths for the Control and Dumpsite locations. The data reveals that, as the depth increases, the pH values for both locations tend to decrease. At 10 cm, the Control has a pH of 6.86, while the Dumpsite has a slightly higher value of 7.12. As the depth increases to 40 cm, the pH values for both locations decrease, with the Control reaching 6.12 and the Dumpsite reaching 7.62. This trend indicates a slight increase in pH with increasing depth in the Dumpsite, while the Control shows a more consistent decline. The differences in pH between the two locations could be attributed to various factors such as waste decomposition and leachate infiltration at the Dumpsite, which might alter the acidity or alkalinity of the soil over depth.

### 4.1.2 Relationship Between Depth and Bulk Density

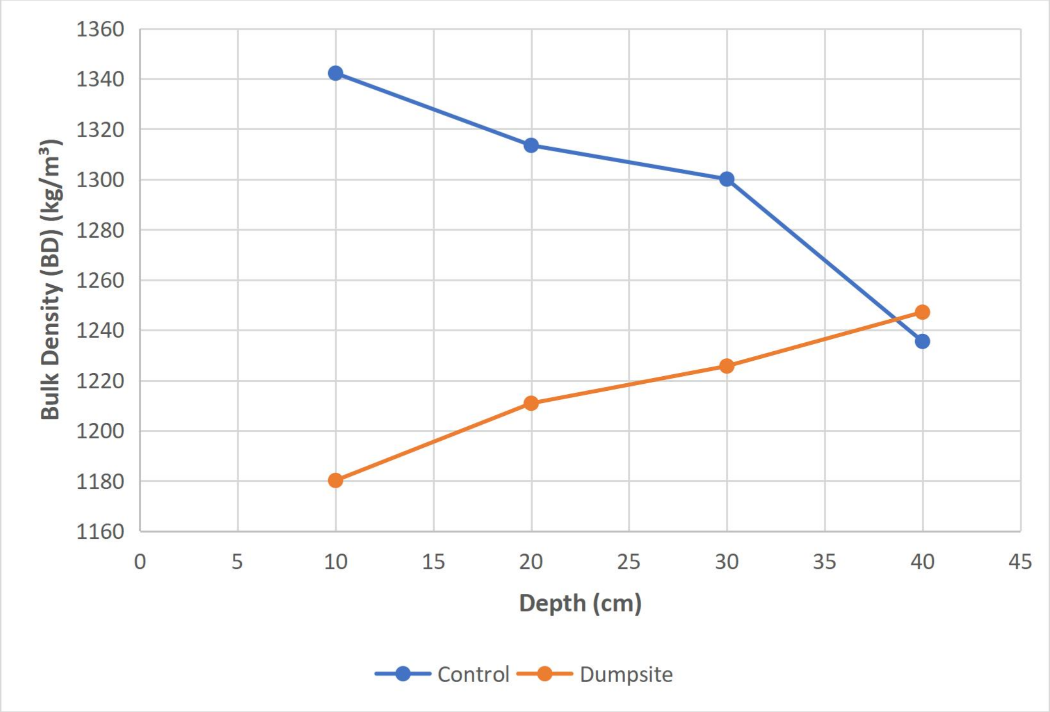

Figure 4. 2: Graph showing the relationship between Depth and Bulk Density

Figure 4.2 shows the bulk density values at different depths for the Control and Dumpsite locations. The data reveals a decreasing trend in bulk density as the depth increases in both locations. At 10 cm, the Control has a bulk density of 1342.21 kg/m³, which is higher than the Dumpsite's value of 1180.17 kg/m³. As the depth increases to 40 cm, the bulk density in the Control decreases to 1235.5 kg/m³, while the Dumpsite shows a more gradual increase, reaching 1247.12 kg/m³. This suggests that the Dumpsite area experiences a slight increase in bulk density with depth, possibly due to the accumulation of waste materials, while the Control location exhibits a more typical decrease in bulk density with increasing depth. These variations could reflect changes in soil compaction, moisture content, or the influence of organic matter at the Dumpsite.

### 4.1.3 Relationship Between Depth and Porosity

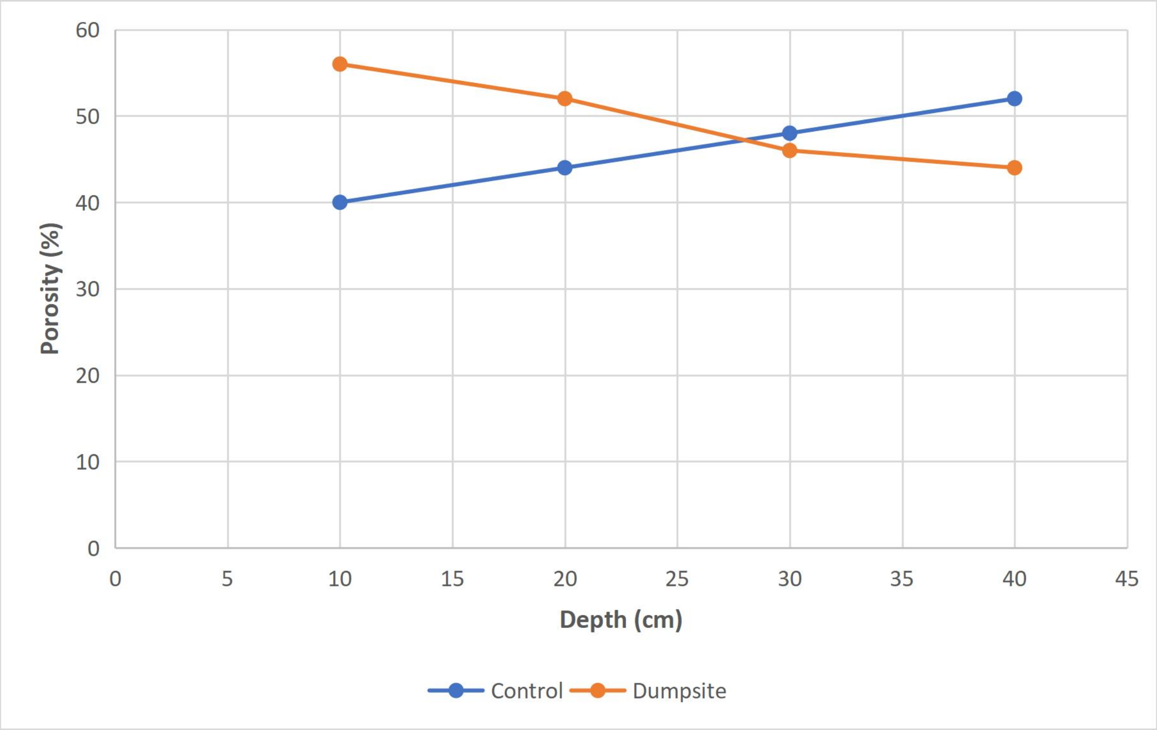

Figure 4. 3: Graph showing the relationship between Depth and Porosity

Figure 4.3 shows the porosity values at different depths for the Control and Dumpsite locations. The data indicates an inverse relationship in porosity between the two locations as the depth increases. In the Control, porosity increases consistently from 40% at 10 cm to 52% at 40 cm. In contrast, the Dumpsite shows a decline in porosity with increasing depth, starting at 56% at 10 cm and decreasing to 44% at 40 cm. This trend suggests that the Dumpsite area experiences a reduction in soil pore space with depth, potentially due to the compaction and accumulation of waste materials, whereas the Control location exhibits a natural increase in porosity, possibly linked to a more stable and less disturbed soil structure. These differences highlight the impact of waste deposition on soil properties at the Dumpsite compared to the more natural conditions at the Control site.

### 4.1.4 Relationship Between Depth and Organic Matter

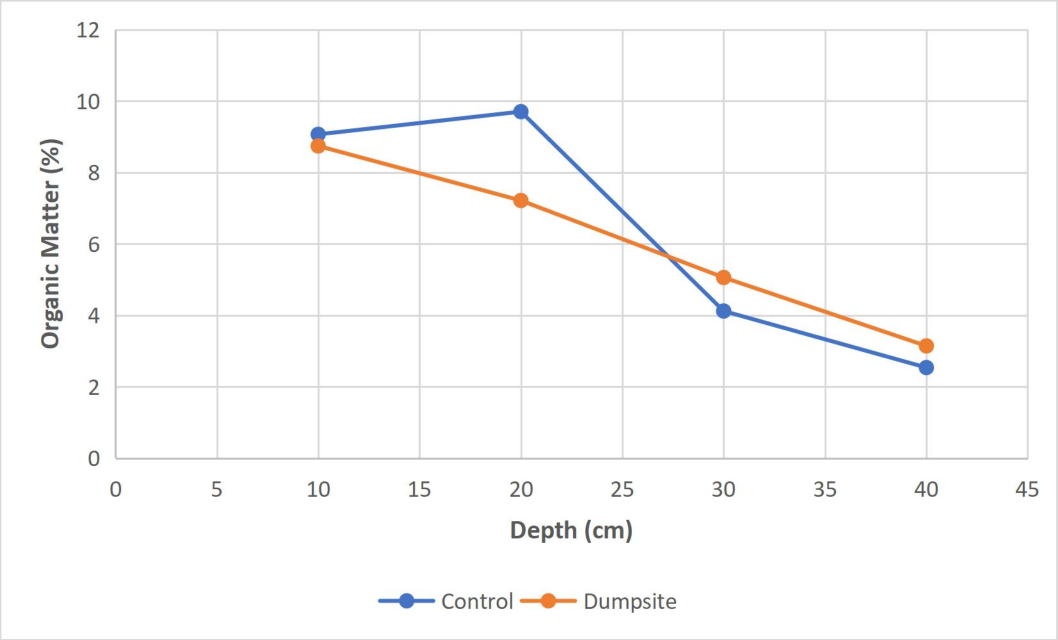

Figure 4. 4: Graph showing the relationship between Depth and Organic Matter

Figure 4.4 shows the organic matter percentage at different depths for the Control and Dumpsite locations. The data reveals a declining trend in organic matter content with increasing depth for both locations, though the decrease is more pronounced in the Dumpsite. At 10 cm, the Control has 9.065% organic matter, which is slightly higher than the Dumpsite's value of 8.74%. As the depth increases, the organic matter percentage in the Control decreases gradually to 2.54% at 40 cm. In contrast, the Dumpsite shows a more significant decrease, dropping from 8.74% at 10 cm to 3.146% at 40 cm. This suggests that organic matter decomposition and microbial activity in the Dumpsite may be more intensive, leading to a faster breakdown of organic material compared to the Control. The lower organic matter at deeper layers in the Dumpsite could also be linked to the accumulation of waste and altered soil conditions, which may hinder organic material preservation.

### 4.1.5. Relationship Between Depth and Electrical Conductivity

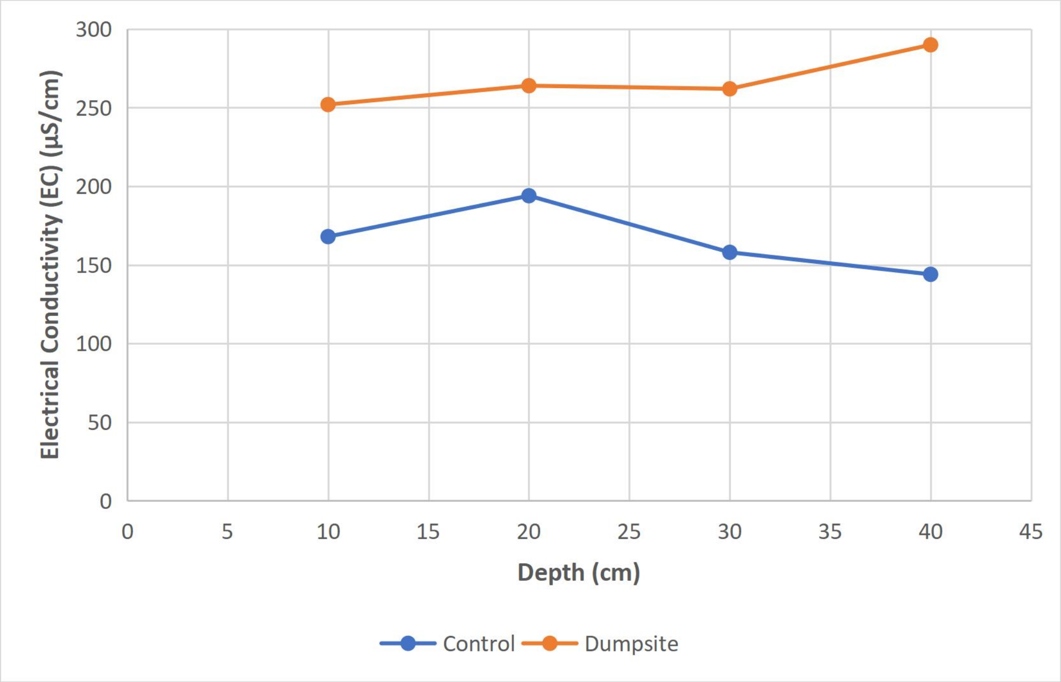

Figure 4. 5: Graph showing the relationship between Depth and Electrical Conductivity

Figure 4.5 shows the electrical conductivity (EC) values at different depths for the Control and Dumpsite locations. The data indicates a higher EC in the Dumpsite compared to the Control at all depths. At 10 cm, the EC in the Control is 168 µS/cm, while in the Dumpsite, it is significantly higher at 252 µS/cm. As the depth increases, the EC in the Dumpsite continues to rise, reaching 290 µS/cm at 40 cm, while the EC in the Control decreases, dropping to 144 µS/cm at 40 cm. This trend suggests that the Dumpsite has elevated levels of soluble ions, likely due to leachate from waste materials, which leads to higher conductivity. In contrast, the Control site shows a decline in EC with increasing depth, which could be attributed to less ion concentration or the lack of anthropogenic influences. These results highlight the impact of waste contamination on the ion content of the soil at the Dumpsite.

## 4.2 HEAVY METAL ANALYSIS

### 4.2.1 Heavy Metal Concentrations at Different Depths

Heavy metals are present at varying concentrations across different soil depths, indicating potential contamination and leaching over time. Table 4.3 shows the heavy metal concentrations at different depths for the dumpsite samples.

Table 4. 3: Heavy Metal Concentrations at Different Depths (Dumpsite samples)

| Sample | Depth (cm) | Replicate | Lead (Pb) (mg/kg) | Copper (Cu) (mg/kg) | Iron (Fe) (mg/kg) | Manganese (Mn) (mg/kg) |
|---|---|---|---|---|---|---|
| A | 10 | 1 | 12.52 | 74.29 | 627.14 | 29.63 |
| | | 2 | 12.44 | 72.62 | 622.42 | 28.65 |
| | | 3 | 11.98 | 75.74 | 598.86 | 29.31 |
| B | 20 | 1 | 7.59 | 39.53 | 415.27 | 13.23 |
| | | 2 | 7.33 | 39.55 | 414.35 | 13.33 |
| | | 3 | 6.85 | 40.02 | 420.69 | 13.69 |
| C | 30 | 1 | 4.15 | 21.44 | 268.95 | 8.25 |
| | | 2 | 4.12 | 21.39 | 261.20 | 8.45 |
| | | 3 | 4.35 | 21.87 | 259.01 | 7.22 |
| D | 40 | 1 | 4.3 | 13.63 | 112.69 | 7.94 |
| | | 2 | 4.46 | 12.90 | 101.91 | 7.87 |

|  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|
|  |  | 3 | 4.44 | 12.14 | 112.45 | 7.99 |

Table 4.4 shows the heavy metal concentrations at different depths for the Control site samples.

Table 4. 4: Heavy Metal Concentrations at Different Depths (Control Samples)

| Sample | Depth (cm) | Replicate | Lead (Pb) (mg/kg) | Copper (Cu) (mg/kg) | Iron (Fe) (mg/kg) | Manganese (Mn) (mg/kg) |
|---|---|---|---|---|---|---|
| A(Control) | 10 | 1 | 12.52 | 58.22 | 296.16 | 17.52 |
|  |  | 2 | 12.44 | 56.22 | 256.18 | 17.56 |
|  |  | 3 | 11.98 | 57.97 | 279.99 | 17.67 |
| B(Control) | 20 | 1 | 2.37 | 27.46 | 143.82 | 11.21 |
|  |  | 2 | 2.59 | 27.81 | 152.01 | 12.02 |
|  |  | 3 | 2.57 | 25.13 | 142.93 | 12.58 |
| C(Control) | 30 | 1 | 2.69 | 12.68 | 73.53 | 10.57 |
|  |  | 2 | 2.54 | 13.74 | 72.52 | 10.58 |
|  |  | 3 | 2.86 | 12.65 | 72.69 | 10.56 |
| D(Control) | 40 | 1 | 2.36 | 11.55 | 46.29 | 9.73 |
|  |  | 2 | 2.12 | 11.71 | 42.52 | 9.01 |
|  |  | 3 | 2.75 | 10.34 | 40.08 | 8.99 |

The mean heavy metal concentrations provide insight into the overall contamination levels and distribution trends across the soil profile. Table 4.5 presents the mean heavy metal concentrations at different depths for the dumpsite samples, highlighting elevated levels compared to background values.

Table 4. 5: Mean Heavy Metal Concentrations at Different Depths (Dumpsite Samples)

| **Sample** | **Depth (cm)** | **Lead (Pb) (mg/kg)** | **Copper (Cu) (mg/kg)** | **Iron (Fe) (mg/kg)** | **Manganese (Mn) (mg/kg)** |
|---|---|---|---|---|---|
| A | 10 | 12.31 | 74.22 | 616.14 | 29.19 |
| B | 20 | 7.26 | 39.70 | 416.77 | 13.42 |
| C | 30 | 4.21 | 21.57 | 263.05 | 7.97 |
| D | 40 | 4.23 | 12.89 | 111.02 | 7.93 |

Similarly, Table 4.6 shows the mean heavy metal concentrations at different depths for the control samples, offering a baseline for comparison and reflecting lower contamination levels.

Table 4. 6: Mean Heavy Metal Concentrations at Different Depths (Control Samples)

| **Sample (Control)** | **Depth (cm)** | **Lead (Pb) (mg/kg)** | **Copper (Cu) (mg/kg)** | **Iron (Fe) (mg/kg)** | **Manganese (Mn) (mg/kg)** |
|---|---|---|---|---|---|
| A (Control) | 10 | 4.24 | 57.47 | 277.64 | 17.58 |
| B (Control) | 20 | 2.70 | 26.80 | 146.25 | 11.99 |
| C (Control) | 30 | 2.51 | 13.02 | 72.91 | 10.57 |
| D (Control) | 40 | 2.41 | 11.20 | 42.96 | 9.24 |

### 4.2.2 Heavy Metal Concentrations Comparison with Control Samples

#### 4.2.2.1 Lead (Pb) Concentrations

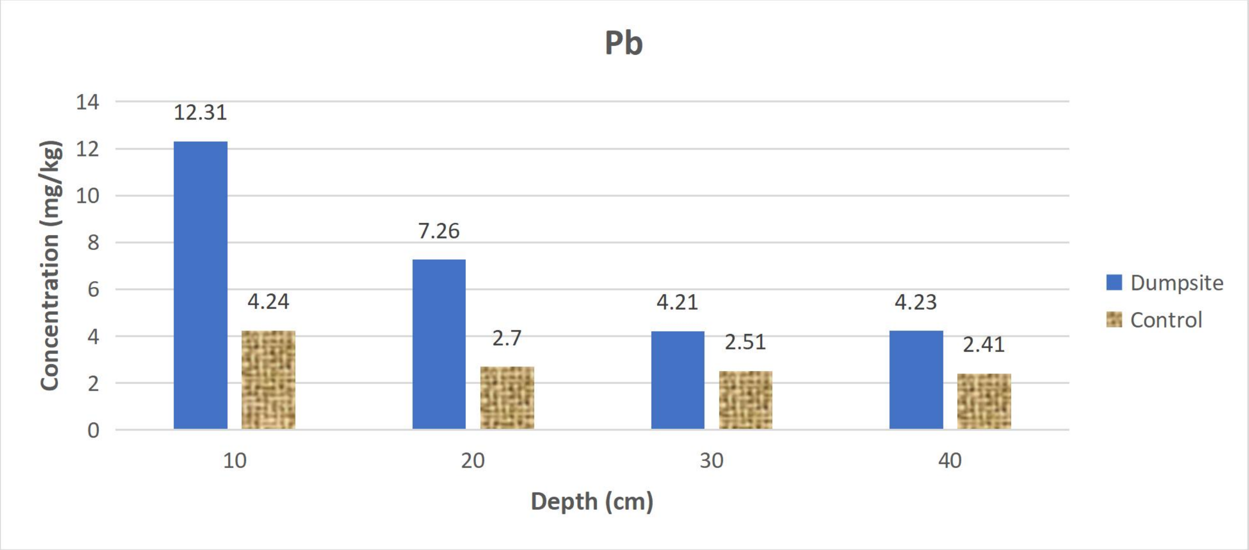

Figure 4. 6: Relationship Between Lead (Pb) Concentration and Soil Depth for Dumpsite and Control Samples

Figure 4.6 illustrates the relationship between lead (Pb) concentration and soil depth for both dumpsite and control samples. The graph shows that lead concentrations in the dumpsite samples consistently exceed those in the control samples at all depths, indicating significant contamination. At 10 cm, the dumpsite records the highest lead level (12.31 mg/kg) compared to 4.24 mg/kg at the control site. As depth increases, lead concentrations decrease for both sites, with the lowest levels observed at 40 cm (4.23 mg/kg for the dumpsite and 2.41 mg/kg for the control). This trend suggests that lead contamination is more pronounced in surface layers and diminishes with depth, potentially due to limited vertical migration.

#### 4.2.2.2 Iron (Fe) Concentrations

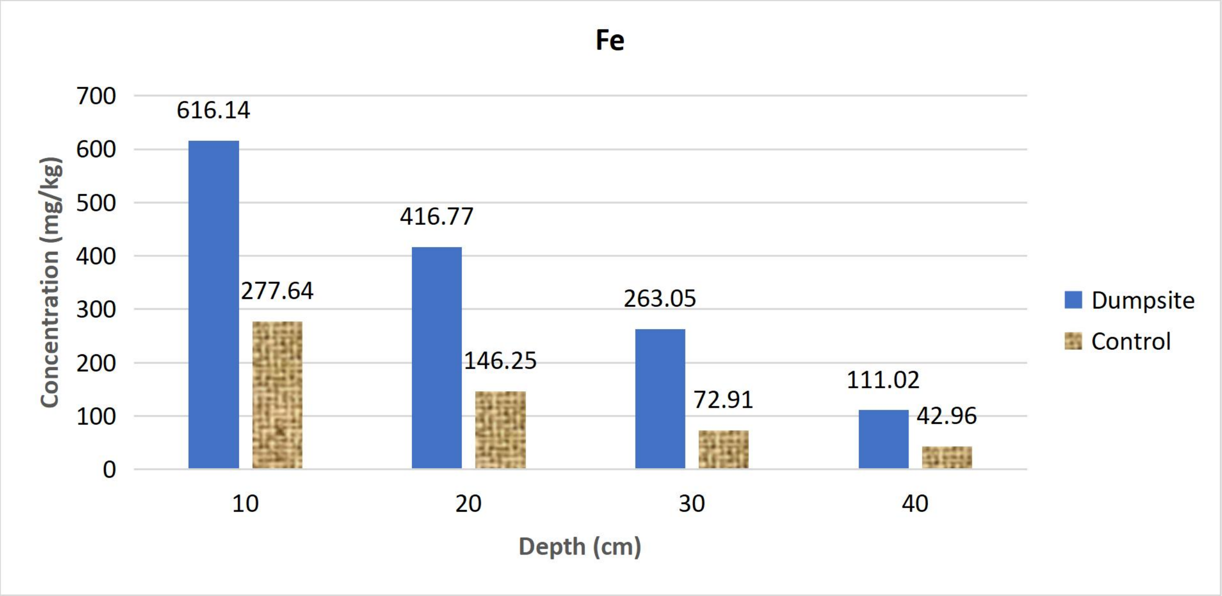

Figure 4. 7: Relationship Between Iron (Fe) Concentration and Soil Depth for Dumpsite and Control Samples

Figure 4.7 illustrates the relationship between iron (Fe) concentration and soil depth for both dumpsite and control samples. The graph reveals consistently higher iron concentrations at the dumpsite across all depths compared to the control site, indicating significant contamination. At 10 cm, the dumpsite shows the highest iron concentration (616.14 mg/kg) versus 277.64 mg/kg at the control site. As depth increases, iron levels decrease progressively, with the lowest concentration recorded at 40 cm (111.02 mg/kg for the dumpsite and 42.96 mg/kg for the control). This pattern suggests that iron contamination is most severe in surface layers, with reduced penetration into deeper soil strata.

### 4.2.2.3 Copper (Cu) Concentrations

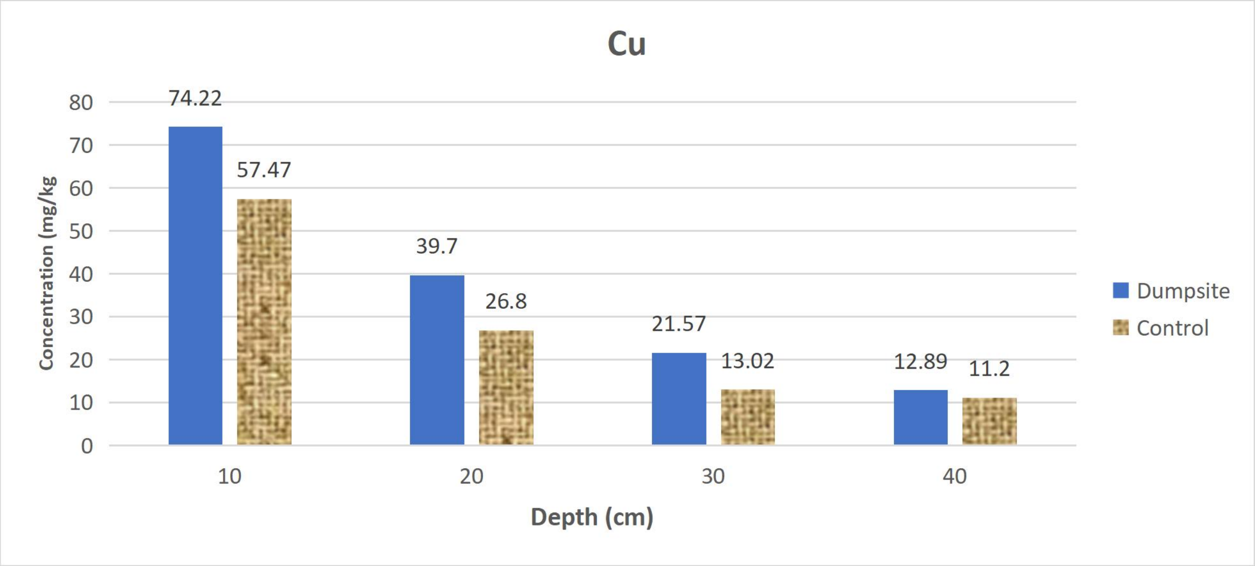

Figure 4. 8: Relationship Between Copper (Cu) Concentration and Soil Depth for Dumpsite and Control Samples

Figure 4.8 presents the relationship between copper (Cu) concentration and soil depth for dumpsite and control samples. Copper levels are consistently higher in the dumpsite samples, indicating contamination across all depths. The highest concentration is observed at 10 cm (74.22 mg/kg), while the control sample at the same depth shows a lower value of 57.47 mg/kg. As depth increases, copper concentrations gradually decline at both sites, reaching their lowest at 40 cm (12.89 mg/kg for the dumpsite and 11.20 mg/kg for the control). This decline suggests copper accumulates near the surface at the dumpsite, with minimal penetration to deeper layers.

### 4.2.2.4 Manganese (Mn) Concentrations

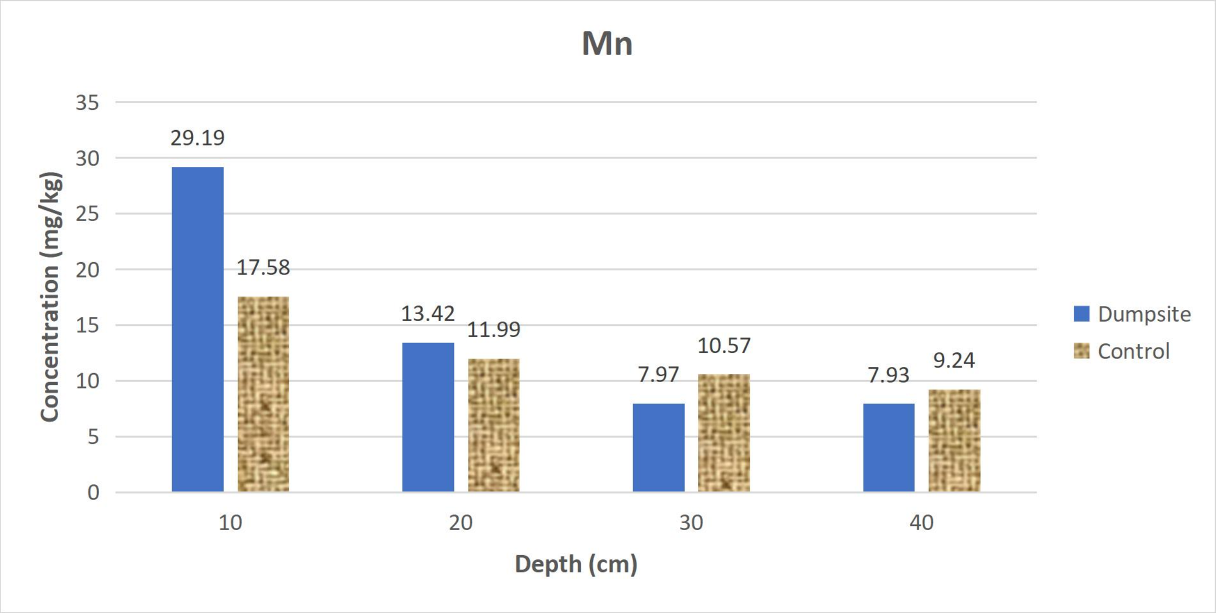

Figure 4. 9: Relationship Between Manganese (Mn) Concentration and Soil Depth for Dumpsite and Control Samples

Figure 4.9 illustrates the relationship between manganese (Mn) concentration and soil depth for dumpsite and control samples. Manganese levels are higher at the dumpsite across most depths, indicating potential contamination. At 10 cm, the dumpsite shows a concentration of 29.19 mg/kg, while the control records 17.58 mg/kg. As depth increases, manganese concentrations decrease, with the lowest values at 40 cm (7.93 mg/kg for the dumpsite and 9.24 mg/kg for the control). Unlike other metals, the difference between dumpsite and control samples narrows at deeper layers, suggesting manganese may leach or migrate more evenly through the soil profile.

## 4.3 DISCUSSION AND IMPLICATION OF FINDINGS

### 4.3.1 Correlation Between Physicochemical Properties and Heavy Metal Concentrations

The correlation between physicochemical properties and heavy metal concentrations in soil is significant, as factors such as pH, bulk density, and electrical conductivity influence the mobility and retention of metals, with lower pH often increasing metal solubility. In this study, higher metal concentrations at shallower depths correspond to higher organic matter and lower bulk density, suggesting that these properties facilitate the accumulation of heavy metals in the soil.

#### 4.3.1.1 Physicochemical Properties and Heavy Metal Concentrations

The relationship between the physicochemical properties of the soil and the concentrations of heavy metals at the solid waste disposal site in Ovia Northeast was explored, and the results indicated that these properties play a significant role in the mobility and retention of heavy metals. The pH of the dumpsite soil samples ranged from 7.12 at 10 cm depth to 7.62 at 40 cm depth (Table 4.1), indicating a neutral to slightly alkaline pH. This pH range was observed to facilitate the mobility of metals such as Lead (Pb) and Copper (Cu). For instance, at a depth of 10 cm, the Pb concentration was found to be 12.31 mg/kg, while Cu was 74.22 mg/kg (Table 4.1), both of which were significantly higher than the control samples, where Pb and Cu concentrations at the same depth were 4.24 mg/kg and 57.47 mg/kg, respectively (Table 4.2). The organic matter content in the dumpsite soil decreased with depth, from 8.74% at 10 cm to 3.15% at 40 cm (Table 4.1). The organic matter was reported to be crucial in retaining heavy metals in the soil, with higher organic matter generally associated with lower concentrations of metals in the soil. This pattern was observed at the 20 cm depth in the dumpsite, where the Pb concentration decreased to 7.26 mg/kg, coinciding with a drop in organic matter content to 7.21% (Table 4.1). The results showed that soils with higher organic content are better at immobilizing heavy metals, corroborating findings from other studies that suggest organic matter helps in binding metals and reducing their bioavailability.

#### 4.3.1.2 Comparison to Previous Studies

The experimental results were compared to those reported in other studies, particularly focusing on the relationship between soil properties and heavy metal contamination in similar environments. Studies by (Egbon et al., 2024) and (Ihedioha et al., 2017) indicated that neutral to slightly alkaline pH levels enhance the mobility of metals like Pb and Cu, which aligns with the findings from this study. Specifically, the Pb and Cu concentrations were higher at the 10 cm depth in the dumpsite samples (12.31 mg/kg and 74.22 mg/kg, respectively), consistent with other reports from contaminated sites with similar pH levels. Additionally, the drop in heavy metal concentrations with depth was observed in both this study and the work of (Cao et al., 2018), where the concentrations of Pb and Cu decreased as the depth increased. In contrast, the control samples exhibited significantly lower metal concentrations across all depths, suggesting that the presence of contamination in the dumpsite soil is likely affecting the metal retention and mobility. This is supported by the findings of (Deka & Sarma, n.d.) , who also observed that heavy metal concentrations were higher in contaminated soils compared to control soils in the same region.

#### 4.3.1.3 Consistencies and Discrepancies

Consistencies were observed in the data, particularly in the way that pH and organic matter influenced the mobility and retention of heavy metals. The higher concentrations of Pb and Cu at the 10 cm depth in the dumpsite samples were consistent with other studies, confirming that pH levels and organic content significantly influence metal mobility. However, some discrepancies were noted when comparing this study to research conducted in different regions. For example, while organic matter was found to have a strong immobilizing effect on heavy metals in this study, similar studies in temperate regions reported weaker effects of organic matter on metal retention (Montiel-Rozas et al., 2016) . These discrepancies could be due to differences in soil composition, moisture levels, and microbial activity between temperate regions and the tropical conditions of Ovia Northeast. Additionally, while Pb and Cu concentrations were consistently higher in the dumpsite samples, the concentrations of Mn and Fe were relatively low across both the dumpsite and control samples, suggesting that these metals might behave differently in the context of the Ovia Northeast site. It is possible that the environmental conditions at the site, such as the soil's bulk density and electrical conductivity, which varied across depths (Table 4.1), influenced the distribution and availability of Mn and Fe more than Pb and Cu.

### 4.3.2 Potential Environmental and Health Impacts of Observed Contamination

The observed contamination of heavy metals such as lead (Pb), copper (Cu), iron (Fe), and manganese (Mn) in the dumpsite soil poses significant environmental and health risks. Heavy metal contamination in soil can lead to bioaccumulation in plants and animals, ultimately entering the human food chain, thus presenting potential risks to human health, including developmental and cognitive impairments, kidney damage, and cancer (Ochieng et al., 2019; WHO, 2011). The high concentrations of Pb and Cu, particularly at shallow depths (10 cm), exceed the permissible limits for soil contamination set by the World Health Organization (WHO) and the Food and Agriculture Organization (FAO). For instance, the WHO guidelines recommend that Pb levels in soil should not exceed 50 mg/kg for agricultural use (FAO/WHO, 2001), while in the dumpsite samples, Pb levels reached up to 12.31 mg/kg at 10 cm depth. While the control samples show lower concentrations of these metals, the levels at the dumpsite indicate severe contamination. Such elevated metal concentrations can severely affect plant growth, soil fertility, and the health of organisms relying on the soil for habitat and nourishment (Li et al., 2017). The contamination may also disrupt the microbial communities essential for nutrient cycling, leading to reduced soil biodiversity (Yang et al., 2015). In comparison, similar studies in West African regions have reported heavy metal concentrations that exceed the WHO/FAO permissible limits, indicating widespread contamination issues due to urbanization, improper waste disposal, and industrial activities (Davies et al., 2016). These findings highlight the importance of monitoring and addressing soil pollution, particularly in regions with industrial activity or waste disposal. The practical implications of these results are significant for soil management and remediation strategies. Soil remediation techniques such as phytoremediation, bioremediation, and soil washing could be explored to reduce the contamination levels and restore soil health (Murtaza et al., 2018). Furthermore, sustainable land use practices must be promoted to prevent further contamination, such as reducing industrial waste disposal in urban areas and implementing land-use zoning regulations. Soil management practices should include regular monitoring of heavy metal concentrations and the adoption of best practices to mitigate the impact of contamination, ensuring the health of both the environment and the populations dependent on these lands for agricultural and other purposes.

# CHAPTER 5

# CONCLUSION AND RECOMMENDATION

## 5.1 CONCLUSION

The goal of this study was to evaluate the heavy metal content and physicochemical properties of the soil at a solid waste disposal site in Ovia Northeast. The concentrations of heavy metals, including lead (Pb), copper (Cu), iron (Fe), and manganese (Mn), were analyzed at different depths (10 cm, 20 cm, 30 cm, and 40 cm) to assess the extent of contamination and its correlation with soil properties such as pH, bulk density, porosity, electrical conductivity, and organic matter. The study found that the heavy metal concentrations were highest at the shallowest depths and decreased with depth, suggesting that surface soil is more susceptible to contamination due to environmental and anthropogenic factors.

The physicochemical properties of the soil, particularly the pH and organic matter content, showed significant influence on the mobility and retention of heavy metals, with a more acidic and organic-rich soil facilitating the absorption and retention of metals. These findings align with similar studies in other regions, which highlight the importance of soil properties in determining the fate of heavy metals in contaminated environments. Additionally, the results demonstrate the potential environmental risks posed by the contamination, with implications for land use and agricultural practices in the area. The heavy metal levels found in the study were compared to permissible limits set by organizations such as the World Health Organization (WHO) and Food and Agriculture Organization (FAO), revealing that some concentrations exceeded the recommended thresholds, indicating a need for immediate remediation actions. The study provides valuable insights for soil management strategies, emphasizing the need for regular monitoring, remediation, and sustainable land management practices to mitigate the risks associated with soil contamination.

## 5.2 RECOMMENDATIONS

The following recommendations should be looked at;

1. Implement appropriate remediation techniques such as phytoremediation or bioremediation to reduce the heavy metal concentrations in the contaminated soil and restore its ecological balance.
2. Establish a continuous soil monitoring program to track heavy metal concentrations over time, ensuring that they remain within safe limits for both human and environmental health.
3. Introduce soil amendments, such as organic matter and lime, to enhance soil structure, reduce metal bioavailability, and improve overall soil health for safer land use.
4. Temporarily restrict the use of contaminated land for agricultural or residential purposes until effective remediation measures are applied, to prevent exposure to toxic metals.
5. Educate the local community on the risks of heavy metal contamination and promote better waste management practices to minimize future soil contamination.

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