ENVIRONMENTAL IMPACTS OF SOLID WASTE MANAGEMENT PRACTICES IN MURANG'A COUNTY, KENYA

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DECLARATION

Declaration by Candidate

This Research Project Report is my original work and has not been presented for award of a degree in any other University.

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Signed………………………...   Date……………………………….

Declaration by Supervisor

This research project report has been submitted for examination with my approval as the University supervisor.

Dr. Salome Muriuki

Signed………………………...   Date………………………………...

Department of Environmental Sciences and Education

DEDICATION

This project is dedicated to my parents, who despite the hard-economic times prevailing especially during my Primary and Secondary Education, worked very hard to see that all of their eight children had a meaningful education. They particularly made sure I went through the four stages of my education uninterrupted. Thanks to my son for the support, he accorded me especially during the two years of my Masters Studies.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS AND ABBREVIATIONS

FHH: Farm Household Head

GPS: Global Positioning System

SPSS: Statistical Package for Social Sciences

UNEP: United Nations Environmental Program

WWF: World Wide Fund

ABSTRACT

Waste management is a global concern due to the amount of waste produced. Globally, 2.01 billion tons of solid waste is produced annually with 33 percent of waste not managed safely. By 2050 waste generated is predicted to increase to 3.40 billion tons annually. Despite the weight of these threats on ecological balance, limited research has been conducted regarding the evaluation of the degree of which poor solid waste management practices influence the environment. This research therefore assessed the environmental impact of waste management in Kiharu Sub-County in Murang'a County, Kenya. More specifically, the study sought to identify the types of solid wastes produced in Kiharu Sub-County, investigate the key components of waste management system, to determine the environmental impacts of solid waste management practices and lastly to investigate the challenges of effective waste management practices and their impact on the environment in Kiharu Sub-County. The study adopted a descriptive cross-sectional quantitative research design and targeted 19,404 households in Kiharu-sub-county. From the population, a sample of 200 was obtained. The data was collected using a questionnaire which was entered and analyzed using SPSS version 27.0. Descriptive statistical analysis was then conducted where statistics such as mean, frequency, standard deviation and percentage were produced. Pearson's correlation and regression analysis were used under inferential analysis to examine association between waste management and environmental impact. From the findings, the study established that there was significant and positive association between solid waste management practices, application and effectiveness of waste management systems and the environmental impact. The findings indicated that if the wastes generated by humans such as construction wastes (87.5%), food wastes (96.2%), Agricultural waste (94.6%) and Waste tires (92.4%) among others were well managed they would lead to a better environment that is clean and healthy. The study established that the community used open landfills and burning waste management practices although they were not effective as they led to degradation of the environment. However, they had adopted reuse, recycling, avoidance and minimization of waste disposal, composting and energy recovery as effective waste management practices. The study also established that there was significant and positive association between solid waste management practices and the environmental impact ($p < 0.05$). The findings indicated that if the wastes generated by humans were well managed through practices would lead to a better environment that is clean and healthy. The study recommended adoption of recycling and re-use methods by setting up recycling centers, awareness creation such as public training and campaigns to the community encouraging households and communities to manage their wastes efficiently, and also reduce reliance on burning and landfills. Lastly, the study recommended the use of modern waste handling equipment to enhance the efficiency and safety of waste management operations.

CHAPTER ONE

INTRODUCTION

1.1 Background Information

Waste management is a public health concern due to the amount of waste produced globally. In the world, 2.01 billion tons of solid waste is produced annually with 33 percent of waste not managed safely. Waste generation per person per day is estimated to range between 0.11 to 4.54 kilograms. Developed countries generate about 683 million tons of the worldwide waste or 34 % of total waste. By 2050 waste generated is predicted to increase to 3.40 billion tons annually (The World Bank, 2022).

Research shows that waste generation is influenced by the income level. High income level countries collect 96 percent of waste, upper-middle income countries collect 82 percent of solid waste, lower-middle income countries collect about 51 percent and low-income countries collect 39 percent of total global solid waste. Although this is the case composition of waste generated differs across income levels. High-income countries produce about 51 percent of dry waste that is recyclable such as glass, and paper and 32 percent of biodegradable waste such as green waste. Conversely, low-income countries generate 53 percent of biodegradable waste and only 20 percent recyclable waste (The World Bank, 2022).

Europe and Central Asia would generate 392 million tons of waste in 2016 and is predicted that by 2030 they will produce 440 million tons and 490 million tons by 2050. Similarly, East Asia and Pacific would produce 468 million tons of waste in 2016 and is projected that by 2030 they will produce 602 million tons and 714 million tons in 2050. North America would produce289 million tons in 2016, projected to generate 342 million tons in 2030 and about 396 million tons by 2050. Likewise, Sub-Saharan Africa would produce 174 million tons in 2016, predicted figure for 2030 is 296 and 516 by 2050. Additionally, Middle East and North Africa would generate 129 million tons in 2016, projected to produce 117 and 255 million tons by 2030 and 2050 respectively (The World Bank, 2022). China has also recorded an increase in the amount of waste generated per year. In 2015 China produced191.42 million tons of waste, 203. 62 million tons in 2016, 215.21 million tons in 2017, 228.02 million tons in 2018, 242.06

million tons in 2019, 235.12 million tons in 2020, 248.69 million tons in 2021 and 244.45 million tons in 2022 (Statista, 2022).

A research by Okumu &Nyenje (2011) showed that Uganda generates0.3 to 0.66 kilograms of waste daily. Waste composition produced in Uganda is made up of organic waste at 92 percent, soft plastics at 3 percent, paper 1 percent, and hard plastic at 2 percent (Komakech *et al*, 2014). Only 28000 tons of solid waste is transported to landfill every month the uncounted waste is dumped in unauthorized areas (Komakech eat al, 2014). Kenya produce 22, 000 tons of waste daily totaling to 8 million tons per year.

Kiharu Sub-County in Murang'a County, Kenya, is not exempted from these developing regions. Improper solid waste management in the region raises concerns because it does not only pose significant environmental threats but also undermines the public health, social well-being, and economic development for residents in the region. In recent years, the region has witnessed rapid population growth, resulting to increased generation of wastes due to population growth and ineffectiveness of existing waste management infrastructure and practices. In many areas within the region, waste is untreated and disposed in open dumpsites, thus increasing the risks of hazardous substances in soil and water bodies and exposing residents to the adverse ramifications of exacerbating pollution and environmental degradation. Poor solid-waste disposal and management may also be attributed to increasing prevalence of air and water pollution, soil degradation, and the propagation of pollution-related diseases (Al-Dailami *et al.,* 2022). Furthermore, poor waste disposal and management practices poses threats on the delicate ecological balance due to the negative impacts it poses on the environment in the region.

Despite the weight of these threats on ecological balance, limited research has been conducted regarding the evaluation of the degree of which poor solid waste management practices influence the environment. Understanding the scale and seriousness of these effects is essential for planning powerful waste administration procedures, strategy execution, and local area commitment initiatives. The research project will seek to connect this knowledge gap by conducting an exhaustive and precise evaluation of the ecological outcomes and environmental consequences of solid waste management practices in Kiharu Sub-County in Murang'a County, Kenya. Using an interdisciplinary approach, consolidating ecological science, prioritizing general wellbeing, and improving the socio-economic variables, the study seeks to provide valuable insights to local specialists, authorities, policymakers, and community networks, thus enabling them devise reasonable, coordinated, and sustainable waste management solutions, preserving the natural environment, and safeguarding the well-being of local residents in the region.

1.2 Statement of the Problem

Poor and improper handling of solid waste in Kiharu Sub-County has led to not only serious ecological repercussions, such as soil and water contamination, loss of biodiversity, and environmental degradation but also significant public health risks, including the spread of diseases, air and water pollution, and increased exposure to hazardous substances. A study by Irawan & Hartoyo (2022) established that the lack of viable waste management practices worsens these challenges, making it crucial to comprehensively assess and address the full scope of these impacts. The need for effective solid waste management is vital for ensuring long-term sustainability and ecological balance in the region. High vulnerability of ground and surface water pollution, as environmental impacts are often overlooked when siting solid waste disposal sites (Sibanda *et al*., 2017). Addressing these challenges is essential to protect both the environment and public health in Kiharu Sub-County.

1.3 Research Questions

The research questions will include the following:

1. What types of solid wastes are generated in Kiharu Sub-County?
2. What are the key components of the waste management system in Kiharu Sub-County?
3. How do waste management practices impact the environment in Kiharu Sub-County?
4. What challenges affect the implementation of effective waste management practices in Kiharu Sub-County, and how do these challenges impact the environment?

1.4 Research Objectives

The general objective of the project will be to investigate the environmental impacts of poor solid waste management practices in the region through four objectives. The attainment of the general objective would necessitate addressing the following specific objectives

1. To identify types of solid wastes produced in Kiharu Sub-County.
2. To investigate the key components of waste management system in Kiharu Sub-County?
3. To determine the environmental impacts of solid waste management practices in Kiharu Sub-County.
4. To investigate the challenges of effective waste management practices and their impact on the environment in Kiharu Sub-County?

1.5 Research Hypothesis

The study hypothesized the following:

H_{01}: Solid waste management practices have no statistically significant effect on environmental quality in Kiharu Sub-County.

H_{02}: The components of solid waste management systems (collection, transportation, disposal, recycling) do not significantly influence environmental degradation in Kiharu Sub-County.

H_{03}: Challenges in implementing effective waste management (e.g., funding, public awareness, infrastructure) do not significantly contribute to environmental pollution in Kiharu Sub-County.

1.6 Justification of the Study

Due to the critical environmental and public health challenges posed by improper waste management practices, the result findings will help the Kiharu Sub- County government in environmental conservation and policy formulation. In essence, the study's findings shed light on the degree and severity of environmental degradation caused by improper waste management practices. The implementation of effective waste management strategies played critical roles in conserving the natural environment, protecting ecosystems, and preserving valuable natural resources for future generations (Irawan &

Hartoyo, 2022). Secondly, the study's research findings provided evidence-based insights to Kiharu Sub-County local authorities and policymakers. The findings of the research will help policymakers implement policies and interventions that will address the poor solid-waste management practices in the Sub- County to adopt sustainable waste management methods, come up with ways of efficient of waste collection systems, and enforce environmental regulations. Lastly, the study findings come helped educate and empower the county residents to contribute more towards sound waste management. The study played an essential role in enhancing positive behavioral changes of the residents in waste segregation and responsible waste disposal.

Therefore, contemporary managers, leaders, and administrators should investigate the detrimental effects of improper waste management on their local environment. The researcher will endeavor in identifying the crucial areas that demonstrate the environmental impacts of the poor waste management practices in Kiharu Sub- County, analyzing the consequences of these practices to the air, soil and water, and recommending sustainable solutions to mitigate these impacts.

1.7 Significance of the Study

This study benefits several stakeholders. First, the findings will benefit the Kiharu Sub-County government by providing evidence-based insights to guide the development of effective environmental policies and waste management strategies. Policymakers will gain a deeper understanding of the extent and effects of improper waste disposal, enabling them to implement sustainable solutions and improve waste collection systems. Second, the study will benefit environmental agencies and development partners by highlighting critical areas of intervention for environmental conservation. Lastly, local residents will benefit through increased awareness and education on proper waste management practices, promoting behavioral change and community participation in safeguarding their environment. The study thus contributes to a cleaner, healthier, and more sustainable living environment in Kiharu Sub-County.

1.8 Assumptions, Scope and Limitation of the study

The proposed research addresses solid-waste management practices in Kiharu Sub-County. The study is aimed to provide a detailed analysis of the waste management practices and their environmental impacts within the unique context by concentrating on a specific geographic area. Further the study examines the current state of solid waste management practices and their environmental effects on residents within the region. The time taken during data collection was determined by the availability of resources and the need to capture representative waste generation patterns and environmental conditions. The research study focuses on recent data to ensure the relevance and accuracy of the findings. The study covers aspects such as waste generation and composition, solid waste management practices, environmental impacts, challenges faced in implanting proper management practices, and recommendations based on findings.

This study was limited to County Council dumpsites and didn’t consider handcrafted dumping sites located in all areas of Kiharu Sub- County.

1.9 Conceptual Framework

The study will integrate key theoretical constructs from existing literature pertaining to solid waste management and its environmental consequences and will employ the Pressure-State-Impact-Response (PSIR) framework as it is widely used in numerous research studies (Lu *et al*., 2022). The PSIR framework recognizes the interrelationships between human activities (Pressure), the environment's condition (State), the resulting changes or effects (Impact), and the measures implemented to address these impacts (Response). In the context of this study, the PSIR framework will guide the assessment of poor solid waste management practices and their environmental impacts as indicated in the figure 1.1

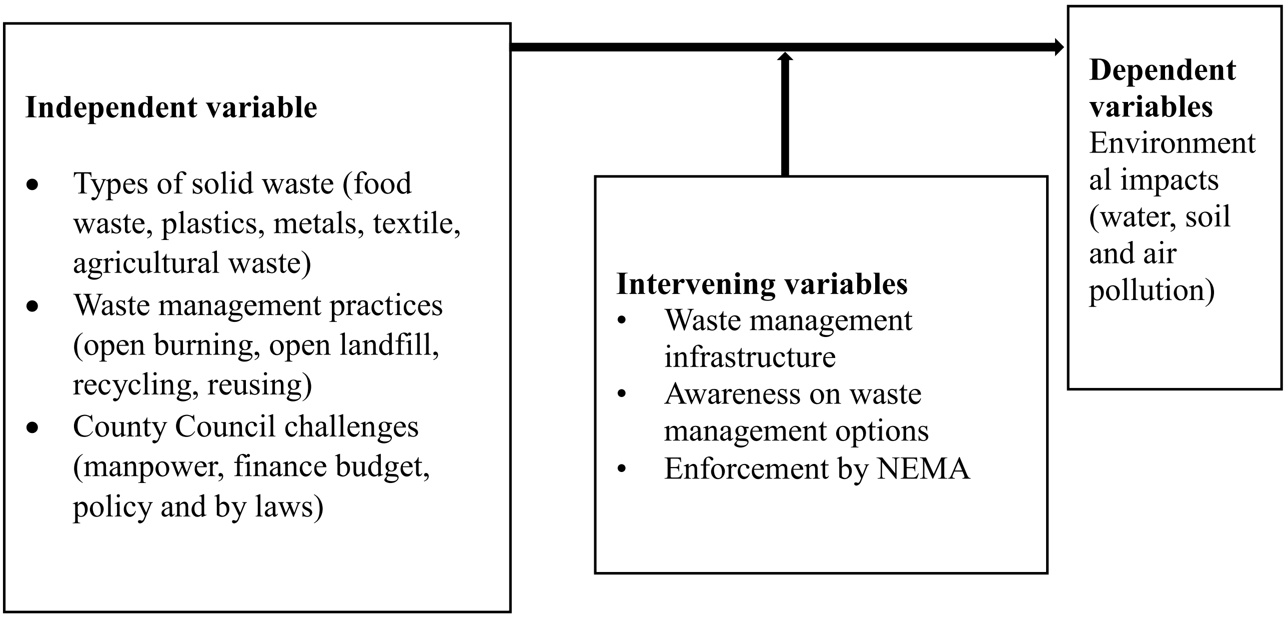

Figure 1.1: Conceptual Framework

Figure 1.1 shows the relationship between independent, intervening and dependent variables used in the study.

1.10 Definition of Terms

Agricultural Waste: Agricultural Waste is unwanted or unsalable materials produced wholly from agricultural operations directly related to the growing of crops or raising of animals for the primary purpose of making a profit or for a livelihood. (Air Quality Management District,, 2023)

Biomedical Waste: Human anatomical waste like tissues, organs and body parts. Animal wastes generated during research from veterinary hospitals. Microbiology and biotechnology wastes (Bansod, 2023)

Chemical Waste: A chemical waste is any solid, liquid, or gaseous waste material that, if improperly managed or disposed of, may pose substantial hazards to human health and environment. (Konrad, 2019)

Community-based interventions: Community-based interventions refer to programs and initiatives that aim to improve the health and well-being of specific population groups within a defined local community (Oregon University, 2020).

Ecological balance: Ecological balance has been defined by various online dictionaries as "a state of dynamic equilibrium within a community of organisms in which genetic, species and ecosystem diversity remain relatively stable, subject to gradual changes through natural succession." and "A stable balance in the numbers of each species (World Wildlife Fund, 2020)

Electronic Waste: E-waste or electronic waste is created when an electronic product is discarded after the end of its useful life. The rapid expansion of technology and the consumption driven society results in the creation of a very large amount of e-waste (United Nations Environmental Programme, 2022)

Food Waste: Food "waste" refers to food that is fit for consumption but consciously discarded at the retail or consumption phases (United Nations Environmental Programme, 2022)

Industrial Waste: An industrial waste is defined as an unwanted by-product or damaged, defective, or superfluous material of a manufacturing process (Nemerow, 2023)

Solid waste management: Solid-waste management, the collecting, treating, and disposing of solid material that is discarded because it has served its purpose or is no longer useful. (Conserve energy Future, 2023)

Waste administration: Provides planning, operational, and contractual models for solid waste management. In most countries, solid waste management responsibility remains local, by default or through decentralization policies. (Yao, 2018)

Waste management infrastructure: In this study waste management infrastructure is the process of obtaining waste from informal waste collectors and industrial plants for processing, then sell products that are processed from the wastes to generate revenue (United Nations Development Program, 2022).

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This section reviews past researches with an aim to synthesize the existing scholarly knowledge on how waste management practices impacts the environment.

2.2 Types of solid waste

Solid waste is any unwanted or discarded materials from human activities such as industrial, mining, commercial, and agricultural operations. Sludge from water treatment is also part of solid waste (EPA, 2024). On the other hand, solid waste management encompasses various elements such as waste generation storage, collection, and disposal of waste (Engineering College Ajmer, 2020). Types of solid waste can be classified according to the source of waste. Each source of waste necessitates specific management practices. These categories include; industrial residential, commercial, construction, institutional, agricultural, and open areas waste.

Table 2:1: Solid waste classification

Source	Type of waste	Waste generators
Industrial	Packaging, food waste, special waste, hazardous waste, construction waste, ashes, chemical wastes	Construction sites, fabrication, chemical plants
Residential	Food leftover, plastic, ashes, vegetable peels, clothes, electronics, batteries, hazardous waste	Apartments, family dwellings
Commercial	Food waste, ashes, metals, glasses, plastics, paper, special waste, and hazardous waste.	Hotels, motels, farm stores, medical facilities
Agricultural	Food waste, pesticides, spoiled vegetables, and grains,	Fields, farms, crops, diaries, orchards, vineyards
Institutional	Plastic, paper, glasses, food waste, bio waste, hazardous waste	Prisons, schools, government offices, hospitals, colleges,
Demolition and Construction	Steel, glasses, concrete, wood, dirt	Construction sites, renovation sites, road repair, and demolitions
Open areas	Food waste, paper, plastic, clothes, litter, waste tires	Streets, parks, beaches, highways, beaches, recreational centers

2.3 Solid Waste Management Practices and Their Environmental Impacts

The increasing volume of waste especially in urban areas associated with growth in economy endangers human health and the environment. According to UNEP (2022), an estimate of 11.2 billion tons of solid waste is collected globally. Hazardous waste such as electronic equipment containing a hazardous substance poses a serious risk in developing and developed countries because of its increased production. Similarly, Kenya produces an estimate of 3000 to 4000 tons of solid waste daily (CM Mwangi, 2021). The highest composition of solid waste produced in Kenya constitutes of organic waste such as food refuse, yard, and agricultural waste (CM Mwangi, 2021).

Poor waste management waste management due to poor collection systems and improper disposal of waste causes soil and water contamination, air pollution, and environment at large. Conversely proper solid waste management practices have positive impact on the environment as it involves; waste minimization and avoidance, recycling and re-using, composting, and open landfills.

Utilization of landfills is a modern method of solid waste disposal that involves adherence to engineering principles to confine waste in a small area, reduce waste volume through compaction, and cover the waste to reduce environmental pollution. Landfills reduce the negative effect of solid waste to public health and environmental nuisance (Ferronato & Torretta, 2019). Landfills can either be open landfills, operated landfills, and sanitary landfills. Developing countries mainly utilize open landfills where solid waste is dumped in an open land haphazardly. Operated landfills where solid waste is compacted and covered each day to prevent pollution. Sanitary landfills are mostly used in developed countries where they have facilities for trapping and treatment of percolates using various ponds (Sankoh, 2020).

According to a study by Sankoh (2020), if landfills are not properly managed, they can pollute the air by producing bad odour due to the breakdown of biodegradable waste by the bacteria. The bad smell poses negative health effects on the people living around the area. Research shows that biodegradation of solid waste produces gas such as carbon dioxide and methane and liquid emissions. Liquid emissions produced percolates in groundwater causing pollution on the water. Similarly, a study by Vaverkova (2019) investigated the impact of landfill on environment concluded that disposal of solid waste in landfills poses major environmental risks. Kenya is yet to upgrade to the modern standard landfills hence utilizes open landfill commonly known as dumpsites within the 47 Counties (Ministry of Environment and Forestry, 2019). These poor management of waste pollute the air due to open burning of waste and production of bad smell on dumpsites, pollute water and soil due to infiltration of waste and impact on aesthetics (Ministry of Environment and Forestry, 2019).

Recycling is the most effective way to preserve the environment. Recycling and reusing materials reduce the amount of solid waste that goes to landfills hence reducing the negative environmental impact of solid waste. According to Osama and Lamma (2021) recycling plastic reduces the tons of raw materials used to produce new ones, similarly, for every tone of paper recycled 18 trees, 7650 gallons of water, and 472 gallons of oil are saved. Research by USAID (2024) shows that only 7 percent of plastics materials are recycled in Kenya, 92 percent is mismanaged leading to 37 kilotons of plastic materials littering the ocean and the environment each year. To reduce this menace recycling rate should be increased. According to EPA (2023), recycling refers to the process of collecting and processing disposable materials that are not needed by their consumers to make new products.

Recycling disposable materials have major benefits on the environment and public health. First, recycling conserves natural resources such as water, mineral products, and trees. Secondly, it reduces the negative impact on climate change. According to EPA (2023) composting and recycling saved about 193 million tons of carbon dioxide. Thirdly, recycling reduces the volumes of waste dumped in landfills hence reducing the effects of pollution (EPA, 2023). Fourthly, recycling reduces the impact on global warming due to reduction in production of Green House gases. Lastly, recycling conserves energy, for instance recycled paper reduced energy consumed by 62 percent, and 94 percent for recycled aluminium (Osama and Lamma, 2021). Different research studying environmental effects of plastic waste recycling on climate change by (Tonini *et al*, 2021) also agrees that recycling of polymers was beneficial to the climate change compared to use of virgin materials.

Composting is also a key method in waste management practices. It is the natural decomposition process of transforming organic waste into helpful product. Organic waste used in composting include market waste, agricultural, kitchen waste, and farm waste. If this waste is left or dumped in the landfills, they produce greenhouse gases which contribute to global warming (Hassan *et al*, 2023). Composting can either be aerobic (requires oxygen) or anaerobic (does not require oxygen) and is affected by temperature, PH, moisture, Aeration, microbial activity, carbon /nitrogen ratio, and lignin content.

A study by Sayara *et al* (2020) demonstrated the that adding compost recovers soil structure by 29 and 63 percent hence reducing risks of erosion, improves drainage, and reduce evaporation of water from the soil. Similarly, application of compost in soil reduces bulky density of soil. According to Sayara *et al* (2020) application of compost in loamy, and sandy soil decreased the soil bulkiness at a rate of 15 to 26 percent and to 14 to 25 percent after 15 months. Moreover, composting reduce waste dumped in landfills and reduce the quantity of methane emitted in landfills hence reducing climatic change (EPA, 2023). Although Sayara *et al* (2020) highlights positive impact on the environment, investigating composting and its impact on climate change with regard to process engineering and compost application-A case study in Vienna found that compositing is associated with emission of carbon-dioxide in the environment hence polluting the air.

Additionally, waste minimization is the process of reducing the amount hazardous waste produced. Environmental Protection Agency establishes three hierarchies of waste minimization which include; source reduction (reducing or eliminating generation of waste), recycling (putting waste material to another use), and treatment which involves neutralization of waste (Purdue University, n.d). A study by Mallak, *et al* (2015) assessing the effectiveness of waste minimization methods in solid waste reduction at the source by manufacturing firms in Malaysia found that after embracing waste minimization at source the quantity of waste generated reduced. There was a positive correlation between waste minimization and waste reduction resulting to a healthier environment. Similarly, research by Mostaghimi & Behnamiam (2022) found a positive correlation between waste minimization and cleaner production strategies.

2.4 Application and Effectiveness of Waste Management Systems

Waste management involves full implementation of procedures available to identify, control, and handle waste. Waste management begins from waste generation to disposal (Mubaslat, 2021). Solid waste management involves various processes, waste generation, collection, storage, and disposal (ugwu *et al*, 2021). Waste generation is the initial stage where materials that are not useful to the owner are disposed. According to UNEP (2024), global waste generation is expected to increase from 2.1 billion tons in 2023 to 3.8 billion tons in 2050. Cost implication on waste management was 361 US Dollars and is predicted to rise to 640 US Dollars by 2050. Conversely, waste prevention could reduce the cost of waste management to 270 US Dollars by 2050.

Developing countries generate more waste than developed countries hence increasing the burden of waste management. Waste generation stage is a crucial stage to start in waste management as it determines the amount of solid waste disposed. Waste is generated at source as raw materials are transformed into new products. For instance, waste in generated from industries, institutions, households, and commercial places. Kenya generates 3000to 4000 tons of solid waste per day. Due to high rate of waste generation the country experiences environmental degradation, and poses dangers to public health (Fine-Consult, 2023). Addressing the issue to waste generation require implementation of 3 R's of waste management reduction of waste, reuse, and recycling alongside with composting, and energy recovery techniques should be implemented. A study by Whitmarsh, Haggar & Thomas, 2018 showed that effective reusing of materials reduces volume of waste generated hence preventing environmental degradation. Similarly, application waste management system can be achieved through recycling. For instance, paper waste can be broken down through pulping to form pulp which is then made into a new paper. Other recyclable materials include plastic, metal and glass. Organic waste can also be recycled through the process of composting to make humus which is beneficial to the soil. Recycling can be achieved through creation of awareness. Research shows that people with recycling knowledge, educated people, older, and wealthier people recycle more (Whitmarsh, Haggar & Thomas, 2018). Similarly, a study conducted in Tehran by Ahmadi (2017) showed that 26 percent of households practice waste reduction, 20 percent re-use their waste, and 29 percent segregate their waste at household level hence the effectiveness of 3 R's in waste management.

The second method for effective solid waste management is through waste collection. In many cities, solid waste is gathered in containers and put in designated places for collection.Waste collection involves door to door collection or indirect collection through communal bins. In high income communities waste collection rate is more than 90 percent and utilizes machined vehicles. In low income regions waste collection is sporadic and mostly inefficient (UNESCAP, n.d).

Effective waste management system in collection can be enhanced through defining frequency of collection, time of collection, and days of collection. The frequency of collection should depend on the rate of waste generation for instance industries are likely to produce more waste than households hence they should be frequented more than the households to ensure effectiveness. Time of the day depends on traffic congestion, regulations, close of business, and weather conditions. Number of collection days depends of the volume of waste generated (UN-HABITAT, 2020). Secondly, effective waste management can be achieved through establishing a central point of collection. Collection point should be accessible for the waste generator and waste collector and should not pose environmental harm or physical harm to residents (UN-HABITAT, 2020).

A study by Il'ko & Peterkova (2023) concurs that the frequency of waste collection in designated areas leads to effective waste management. The study compared weekly collection in mixed and monthly collection of plastic, glass, and paper waste. The researchers found a significant lower percentage of glass on weekly collection compared to monthly collection. Similarly, findings from the study demonstrated low percentage of paper where collection was on weekly basis compared to the monthly collection. These results concurs with suggestions by UN-HABITAT (2020) that claims that frequency of waste collection result to effective waste management

Thirdly, waste storage is essential for effective waste management. Each household, business, institution, and any establishment that produces solid waste must have means of storage. Waste should be segregated as either recyclable, or biodegradable before storage. A study In Tanzania investigating impact of solid waste segregation on recycling found out that waste segregation had a positive impact on the quantity of waste produced. Re-use and recycling of plastics, metals, and electronic increased making the highest percentage of waste generated to be food waste at 60 percent.

Another study investigating waste storage and segregation and its effect on the environment found that the population did not understand the importance of segregating sanitary waste during storage as it is hazardous (Sunitha *et al*, 2023). Lack of awareness about waste segregation causes ineffectiveness in solid waste management. Findings by Pandey, Sahu & Tyagi (2019) concur with these findings.

Lastly, waste disposal is the stage stage of waste management. Various countries use different methods of disposal such as open dumping or dumpsites which involves dumping waste haphazardly without measures to control odour, gasses emitted, dust, or leachate (UNESCAP, n.d). A study in Dandora dumpsite showed a significant correlation of polluted groundwater and distance to the dumpsites (Bruce, 2016). In addition, waste disposal is done through landfill which are either semi-engineered or sanitary landfill. Composting of organic waste, and incineration (UNESCAP, n.d). Similarly, research by Kwateng &Kumah (2022) recommended that effective waste management in Ghana could be achieved through collaborative efforts between Assembly and people, and by ensuring landfills meet the sanitary standard.

2.5 Challenges of Effective Waste Management Practices

Effective waste management is a key issue in both rural and urban areas. Proper waste management exercise are critical to maintaining environmental sustainability, and public health. Nevertheless, many challenges hinder effective waste management systems. These challenges include; institutional challenges, poor enforcement of solid waste management, presence of cartels, and social challenges of lack of awareness (Sibada, Awuor &Nelson, 2017).

Solid waste management is an expensive task and require resources to fund daily operations of vehicles, train personnel, pay personnel, buy the proper equipment, and fund maintenance of the equipment and infrastructure. Lack of financial, logistical, and technical resources is a hindrance to effective solid waste activities. A study by Sibada, Awuor &Nelson (2017) shows that solid waste management activities receive limited allocation of revenue resources making it difficult to purchase new vehicles, and maintain existing vehicles.

Another challenge on solid waste management is social changes. Social challenge includes lack of public awareness of solid waste management practices, bad attitude towards solid waste, and unwillingness to pay for waste services (Hirpe &Yeom, 2021). Waste segregation is a key component of solid waste management, most people lack knowledge about the need to segregate their waste making it difficult for waste collectors. A study by showed that elderly people practiced waste segregation more than younger people because they have learned and heard more about waste segregation (Debrah, Vidal & Dinis, 2021). Emphasis must be put on promoting awareness about solid waste storage and segregation. Similarly, Hirpe &Yeom (2021) agreed that there is lack of willingness to pay for waste services especially in low-income areas making it difficult for private firms to collect waste.

In addition, poor or lack of proper enforcement of solid waste management laws and policies contribute to challenges experienced in the field of solid waste. Poor enforcement of laws and policies are due to lack of coordination between the government and private sector, lack of trained personnel to implement policies, limited resources, lack of necessary infrastructure such as sanitary landfills, treatment plants, lack of legal understanding, and cultural believes on waste (Hirpe &Yeom, 2021). A study by Amugsi, Muindi, &Mberu (2021) concurs that poor implementation and enforcement of existing solid waste management laws is due to corruption, political interference, lack of cooperation from citizens, and lack of political will

Moreover, the presence of criminal cartels in solid waste management hinders effective waste management. These cartels control collection, transportation, and disposal of waste in landfills or dumpsite hence undermining regulatory efforts. Waste management sector is a high profit-making business with minimum risk of getting caught for illegal involvement. Cartels create loopholes in policy implementation hence gaining territorial control. According to Global Initiative against Transnational Organized Crime **(**2020), Dandora dumpsite in Nairobi is controlled by gangs who profit from every truck that lands on the dumpsite. Auditor general in 2018 noted irregularities of tracks on Weigh Bridge where tracks were being double invoiced without garbage. Such complexities make it difficult for effective solid waste management programs to run especially in urban areas. Research by Muindi *et al* (2020), showed that increase in unemployment, poverty causes increase of cartels and criminals in solid waste management posing a challenge to transporters and people recycling in dumpsite.

Lastly, roads leading to dumpsites pose an infrastructural challenge that disrupt waste collection and disposal. As trucks transport the waste, they destroy the roads since they are heavy. A study by Nyamache (2018) shows that he wastes from trucks drop on the road side blocking the trenches leading to flooded roads especially during rainy days. The challenge of infrastructure causes delays in waste collection in residential and commercial areas, increased transportation cost, damaging of vehicles, illegal dumping, pose as a public health hazard due to bad odor and water contamination (Nyamache, 2018).

2.6 Research Gap

Despite the global concern on solid waste management, specific environmental impact on Kiharu Sub-County in Murang'a County is under researched (World Bank, 2022). While many studies focus on environmental impact of solid waste on urban areas, impacts of solid waste practices in Kiharu remain undocumented. This paper highlights gaps that need more focus in Kiharu Sub-County. There is need to assess environmental impact of solid waste management practices in Kiharu since most research focus on urban areas (Kumar *et al*, 2020). Studies neglect the impact of solid waste on soil quality, water, and air.

Secondly, there is insufficient research on comparative analysis of solid waste management approaches suitable for Kiharu Sub-County since most research focus on disposing of solid waste in dumpsites. Although dumpsites are common in urban areas research should focus on environmentally friendly ways to dispose waste in Kiharu such as composting, recycling, reusing, incineration, and landfills (Ferronato & Torretta, 2019). Moreover, modern technologies should be incorporated to reduce recurrent of problems resulting from traditional waste management techniques.

Lastly, there is a research gap on long term environmental monitoring system that shows impact of solid waste on environment (UNEP, 2021). There is a dire need for a system that tracks changes in environment over a period of time to understand long term effect of waste disposal. Kiharu Sub-County requires a system that tracks environmental impact of solid waste practices over the years to understand the effectiveness of strategies implemented in the Sub-County.

CHAPTER THREE

RESEARCH METHODOLOGY AND MATERIALS

3.1 Introduction

This Chapter explores the methodology employed in this research, with an aim to shed more light on the process by which data was collected, analyzed, presented and interpreted building upon the theoretical framework established in the preceding chapters. This section outlines the systematic approach undertaken to address the research objectives. This chapter discusses the study area, the research design, the study population, the sampling technique, sample size, data collection procedure and instrument and lastly data analysis of the data collected.

3.2 Study Area

Location: Kiharu Sub-County is 89 km from Nairobi and 1 hr. 42 minute drive (84.6 km) via Embu – Nairobi road. it is one among the Sub Counties of the larger Murang'a County was formerly known as Mbiri Sub-County between 1966 and1983 and has 6 administrative wards gaturi ward, Township ward, Mbiri ward, Mugoiri ward, Wangu Ward and Murarandia ward. It is located at latitude: -0.719047 and the longitude is: 37.14864. Latitude: -0.719047 Longitude: 37.14864. Latitude DMS: 0°43'8.57 and has a total area of 268.80 km2 and population of 181,076 (Kenya National Bureau of statistics, 2019).

Climate: Kiharu Sub County has a tropical savannah climate (Aw) and it has usually warmer than the neighbouring highlands bordering it just some few kilometers to the east. High temperatures can surpass 35 °C in the months of October to March. Those are the hottest months in the area.

Soils: Soils are sandy, silt, clay and loamy which are distributed in the whole county

Economic Activity: Residents of Kiharu Sub-County participate in a variety of economic activities, with agriculture being the cornerstone of the local economy. The area is renowned for its cultivation of cash crops, alongside subsistence farming and livestock rearing. The construction industry is also growing, driven by the rising demand for housing and infrastructure. Additionally, entrepreneurship thrives in sectors such as retail, services, and hospitality, supported by vibrant local markets and access to microfinance. Together, these activities sustain the local economy and generate employment opportunities for the community.

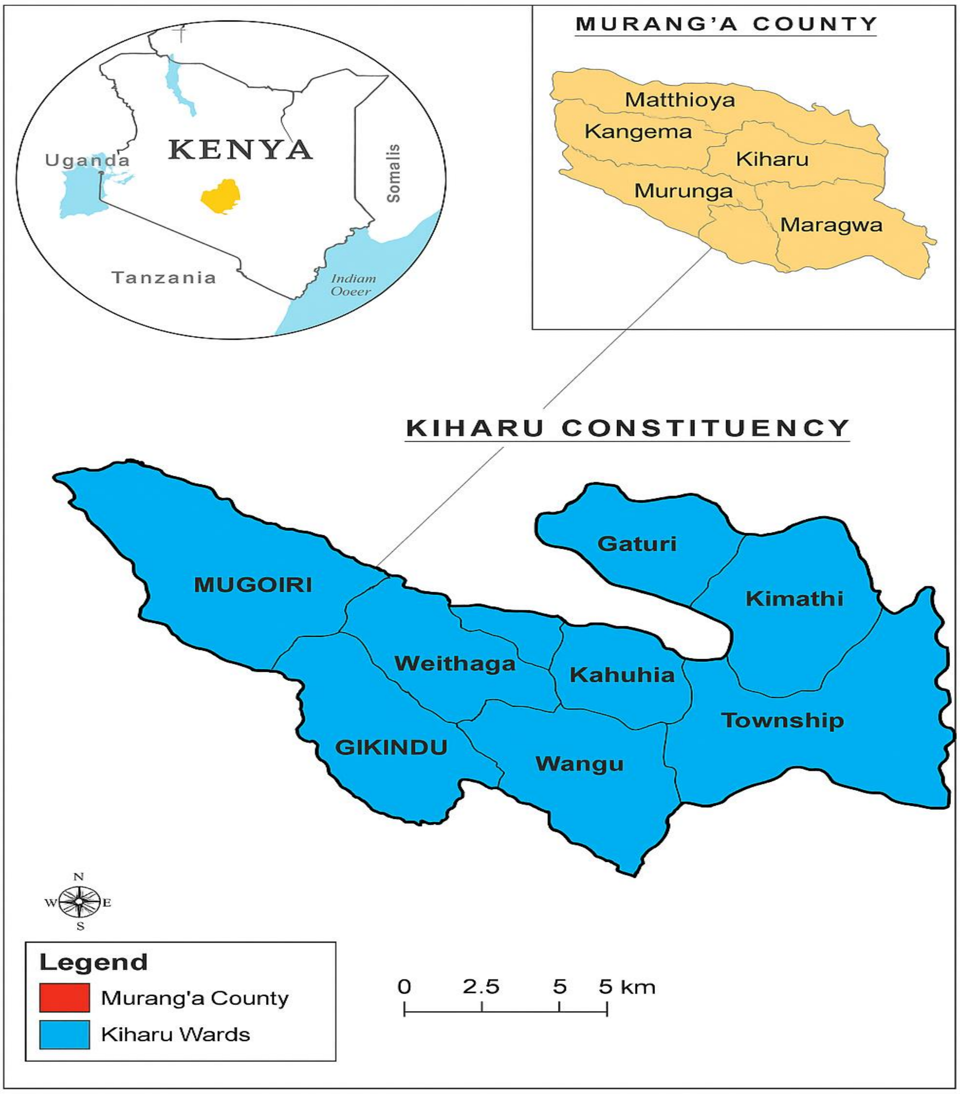

Figure 3.1: A Map of Kiharu Sub-County in Murang'a County

Source: Map of Murang'a County

3.3: Research Design

The study employed a descriptive cross-sectional research approach to collect the data. This design involves collecting data at a specific point in time to describe characteristics, behaviors, or conditions within a defined population without manipulating the study environment. As an observational approach, it is well-suited for measuring the prevalence of specific outcomes and identifying patterns or associations among variables. In this study, the descriptive cross-sectional design was essential for examining the environmental impacts of solid waste management in Kiharu Sub-County, Murang'a County, Kenya. It enabled the researchers to systematically collect and analyze data from households and key informants to assess the types of waste generated, common waste disposal practices, and community perceptions regarding the effectiveness of existing waste management strategies. This approach facilitated the analysis of correlations between different waste management strategies and their impact on the environment, providing insights into community attitudes towards recycling, re-use, composting, and waste-to-energy initiatives. By identifying challenges, the study highlighted their adverse effects on environmental quality, guiding recommendations for improving waste management practices in the region effectively. In essence, cross-sectional quantitative research approach did not only facilitate systematic collection of data but also comprehensive analysis of numerical data (Li *et al*., 2019). Households' heads and the key informants were selected using random sampling and they include, chiefs, business owners, church leaders, school principals, elected government representatives in the County, NEMA and NGO officers, County Council officers in charge of waste collection and disposal in Kiharu Sub- County.

3.4 Study Population

The population refers to an entire set of units that exhibit a variable characteristic under investigation and for which research findings can be generalized (Shukla, 2020). The study targeted all households within Kiharu Sub- County. According to KNBS, (2019), there are 19, 404 households within the study area. The study engaged a diverse range of participants to capture comprehensive data that reflects the realities and perspectives from various groups (Scruggs & Mastropieri, 2021).

3.5 Sampling Procedure

The study employed stratified random sampling technique to select participants from the target population. The researcher categorized and divided the area into distinct strata (Wards within Kiharu). A representative sample from each stratum was selected using snow balling sampling technique to ensure accurate information is collected. A total number of 200 households were selected for analysis and generalizatiability of the results obtained (Slack *et al.*, 2021).

3.6 Sample Size

The study used Nasiurma (2000) to derive the required sample size. The formula is defined as; $n = \frac{NCV^2}{CV^2 + (N-1)\varepsilon^2}$

Where=19,404, $CV =$ Coefficient of Variation $(0.71), \varepsilon =$ error tolerance for 95% confidence interval (0.05)

Therefore; $n = \frac{19{,}404 \times 0.71^2}{0.71^2 + (19{,}404 - 1) \times 0.05^2} = 200$

The researcher distributed questionnaires to 200 households in Kiharu Sub- County. The researcher prioritized households in the industrial regions. This is because these areas generate significant amounts of hazardous waste, making them critical for assessing the effectiveness and challenges of environmental waste management practices.

3.7 Instruments

The study relied on questionnaires to collect quantitative data from the target population. The researcher administered structured questionnaires to residents and several waste management authorities to collect quantifiable data on the waste generation patterns, and waste disposal practices. The questionnaires used close-ended questions, which allowed easy data analysis and comparisons in the research project (Taherdoost, 2022).

A questionnaire was chosen primarily because of the research design chosen and the information and the expected data sought by the study. The questionnaire contained items gotten from independent and dependent variables which largely influenced decisions about waste management and other factors like age, gender, education level and other socio-economic components of the households. The questionnaire assisted in assessing public opinion and awareness on solid waste management practices and their environmental impacts within the region. In a nutshell, quantitative data collected from observations, questionnaires, and surveys provided an in-depth assessment of the environmental impacts of poor solid waste management practices in Kiharu Sub-County. These data enabled the researchers to derive statistically sound conclusions, inform evidence-based recommendations.

3.8 Data collection Procedure

3.8.1: Pre- testing

Pre-testing the questionnaires was done before the actual data collection was carried out. Experts were used including the supervisors who gave insights to the tools. This helped to determine the respondents understanding of the questions to find out whether they have the information being sought by the study and whether they can perform the task required by the study. Pre-testing is also necessary because it provided the most direct proof for the validity and consistency of the questionnaire needed for most items. It gave the researcher an opportunity to modify the questionnaire. To obtain reliable and quality information, research assistants and data enumerators were trained on the approach and the procedure needed in relation to the questionnaires, research ethics, coding of data, arithmetic and quantification skills, the general conversion of the local units to SI or Standard Units, the triangulation and throbbing skills.

3.8.2: Data Collection

Snow ball sampling was applied to select the household heads and the key informants who included, chiefs, business owners, church leaders, school principals, elected government representatives in the County, NEMA and NGO officers, County Council officers in charge of waste collection and disposal in Kiharu Sub- County. In each of the wards, the initial respondents were identified through local leaders and asked to refer other relevant individuals involved or knowledgeable about waste management. This approach allowed the researcher to reach hard-to-identify respondents, such as informal recyclers, local waste handlers, or residents directly affected by industrial waste, thereby creating a chain of referrals that expanded the sample within targeted communities. They were then served with structured questionnaire to fill to obtain in-depth information.

3.9 Data Analysis

Data analysis is a crucial component that involves systematically examining and interpreting the data collected during the research process to address the research questions or hypotheses. It is the process of applying statistical methods to organize, represent, describe, evaluate, and interpret collected data. The collected data was coded, edited, and keyed into Excel computer package to facilitate statistical analysis. Quantitative data was analyzed using Statictical Package for Social Sciences (SPSS) version 27 while the qualitative data was summarized into themes using thematic analysis method. The nature of the data guided data analysis. Mixed methods data analysis methods were employed in this study, including descriptive and inferential data analysis. Descriptive analysis involved summarizing data using frequencies, means, and standard deviations. Mean and standard deviation were widely used for summarizing data due to their simplicity, familiarity, and efficiency. Descriptive statistics provided concise descriptions of central tendency and dispersion, making them accessible to various users and facilitating communication of findings. These statistics were fundamental to inferential techniques and were particularly suited for continuous numerical data analysis. Inferential data analysis was also conducted to answer the research objectives. This involved Pearson's correlation coefficient (r) and linear regression analysis.

Pearson's Correlation (r) is a measure of the significance, direction, and strength of a linear relationship (Correlation) between two variables. In this study, it was used to analyze the linear relationship between the predictor variables and the dependent variable. According to Kothari (2011), an absolute Pearson's correlation value of 0.5 indicates a strong linear relationship between variables, while a value below 0.5 indicates a weak linear relationship. The sign of the correlation coefficient value indicates the direction of the relationship and finally, the resultant p-value less than 0.05 at 95% confidence level indicates that the linear relationship between variables of interest is statistically significant. The 95% confidence level is a commonly used threshold in statistical analysis. Linear regression was then applied to establish a predictive model and test for the significance of the variables. In this study, regression analysis was conducted to determine whether each of the three independent variables – waste management practices, application and effectiveness of waste management systems and challenges affected or impacted the environment in Kiharu. The regression model was as presented in the equation below:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \varepsilon$$

Where:

Y =environmental impact

X_1 = Solid Waste Management Practices

X_2 = Waste Management Systems

X_3 = Challenges to effectiveness of waste management practices

ε = Error term

The results after analysis were presented using tables and graphical techniques.

Table 3.1: Summary of Data analysis

Objective	Type Of Data	Independent Variables	Data Collection Method	Data Analysis
To identify types of solid wastes are produced	Quantitative, binary responses		Questionnaire	Descriptive statistics, Frequencies.
To investigate the key components of waste management system in Kiharu sub-county?	Quantitative, Likert Scale	Waste Management Systems	Questionnaire	Descriptive statistics, Mean, standard deviation
To determine the effect of Solid Waste management practices on the Environmental impact	Quantitative, Likert Scale	Solid Waste Management Practices	Questionnaire, key informants.	Descriptive statistics, Mean, standard deviation Inferential, Pearson's correlation and regression
To investigate the effect of challenges of effective waste management practices on the Environmental Impact	Quantitative, Quantitative, Likert Scale	Challenges of effective waste management practices	Questionnaire, key informants.	Descriptive statistics, Mean, standard deviation Inferential, Pearson's correlation and regression

3.10 Summary

In summary this chapter of the research project outlines the methodology employed, beginning with the adoption of a cross-sectional quantitative research design to address the research questions. The population under study comprises 29,404 households within Kiharu sub-county. A sample of 200 respondents was selected where questionnaires were issued to the household heads using a random Sampling strategy. Primary data were collected through structured questionnaires. The data collection procedure involved obtaining permissions and personally administering the questionnaires. Validity and reliability were addressed through methods such as pretesting questionnaires and using Cronbach's alpha for reliability. Data analysis was conducted using SPSS software, employing descriptive and inferential statistics, including correlation analysis and linear regression to analyze relationships between variables. The chapter laid the groundwork for the research's methodology, ensuring rigor and reliability in the study's findings.

CHAPTER FOUR

RESEARCH RESULTS AND DISCUSSION

4.1 Introduction

This Chapter provided information on the study findings starting with the response rate, demographic characteristics of the study sample, descriptive and inferential findings according to the study's specific objectives. The study sought to assess the environmental impacts of solid waste management practices in Kiharu Sub-County, Murang'a County, Kenya.

4.2 Response Rate

The study targeted a sample size of 200 respondents and the results on questionnaire return rate are presented in Table 4.1.

Table 4.1: Response Rate for the Administered Questionnaires

Response Status	Frequency	Percentages
Responded	186	93.0%
Not responded	14	7.0%
Total	**200**	**100%**

From the results in Table 4.1, a total of 186 questionnaires were returned. This represented a 93.0% response rate which was excellent and sufficient for analysis. Baruch &Holtom (2008) in a study on levels of response rate in researches established that a 50% rate of response was sufficient for analysis.

4.3 Demographic Information of the respondents

4.3.1 Demographic Characteristics

The study analyzed the respondent's demographic information which included the location or ward they came from, their gender, marital status, highest education level, and their source of income.

Table 4.2: Demographic characteristics

		Frequency	Percent	Cumulative Percent
Ward	Gaturi	29	15.6	15.6
	Murarandia	37	19.9	35.5
	Township	31	16.7	52.2
	Kahuro	22	11.8	64.0
	Wangu	30	16.1	80.1
	Mbiri	34	18.3	98.4
	Mugoiri	3	1.6	100.0
	Total	186	100.0	
Gender	Male	109	58.6	58.6
	Female	77	41.4	100.0
	Total	186	100.0	
Marital Status	Single	87	47.0	47.0
	Married	69	37.3	84.3
	Divorced	14	7.6	91.9
	Separated	15	8.1	100.0
	Total	185	100.0	
Highest Education level	None	3	1.6	1.6
	Primary	20	10.9	12.5
	Secondary	68	37.0	49.5
	Tertiary	47	25.5	75.0
	University	46	25.0	100.0
	Total	184	100.0	
Source of income	Business	53	31.9	31.9
	Farming	36	21.7	53.6
	Employment	45	27.1	80.7
	Family support	26	15.7	96.4
	None	6	3.6	100.0
	Total	166	100.0	

From the results in Table 4.2, for their location, the respondents indicated that they were spread across seven wards namely: Gaturi, Murarandia, Township, Kahuro, Wangu, Mbiri, and Mugoiri. Gaturi had 29 participants (15.6%), Murarandia had 37 (19.9%), Township had 31 (16.7%), Kahuro had 22 respondents (11.8%), Wangu had 30 respondents (16.1%), Mbiri had 34 respondents (18.3%), and Mugoiri has the fewest with 3 respondents (1.6%).

Majority of the participants were male (58.6%), while female participants constituted of 41.4%. Regarding marital status, the largest group of respondents were found to be single, constituting of 47.0%, followed by those who were married who constituted of 37.3% while 7.6% indicated to be divorced and lastly 8.1% were separated.

Majority of the respondents had secondary education (37.0%) as their highest education level while those with tertiary education and university education were almost equal, 25.5% having tertiary education and 25.0% having university education. Respondents with primary education constituted of 10.9%, and the rest, 1.6% indicated to have no formal education.

When asked about their source of income, most, 31.9% stated that they did engage in business activities. Farming was found to be the second most common source (21.7%) followed by employment (27.1%), while those who were supported by their family members were 15.7%. A small number, 3.6%, reported to having no source of income.

4.3.2 Summary statistics of age, household, residency period, and income

Table 3 provides summaries of the respondents' age, the number in their household, the period they have lived in the area and their annual income.

Table 4.3: Summary statistics of age, household, residency period, and income

	Minimum	Maximum	Mean	Std. Deviation
Age in years	19	70	31.11	10.852
How many people live in your household	1	12	3.71	2.116
How long have you lived in the area in years	1	50	14.40	12.349
What is your approximate annual Income in Ksh	0	480000	68619.56	89053.709

Based on Table 4.3, the age of the participants ranged between 19 years to 70 years, with a mean age of 31.11 years and a standard deviation of 10.852, indicating moderate age diversity. The results also showed that the household sizes varied from 1 to 12 members, with the average size being 3.71 and a standard deviation of 2.116. The study participants also indicated they had lived in their current area for an average period of 14.40 years with a standard deviation of 12.349, ranging between 1 and 50 years which showed a mix of both newer and long-term residents. Lastly, the estimated annual income of respondents spanned from 0 to Ksh, 480,000 with a mean of Ksh, 68,619.56 and a high standard deviation of 89,053.709, indicating significant income disparity among the participants.

4.4 Solid Waste Management Practices

This section presented a summary of the study variables on waste management and the environmental impact.

4.4.1 Types of solid waste and solid waste management practices

Types of solid waste

The respondents were asked to state the types of wastes generated by humans in their area. Table 4.4 presents the various types of solid waste found in Kiharu, Murang'a. Most generated wastes came from food wastes, agriculture, waste tires and construction activities.

Table 4.4: Types of solid waste in Kiharu, Murang'a

	Yes %	No %
Construction waste	161 (87.5%)	23 (12.5%)
Electronic Waste	102 (55.1%)	83 (44.9%)
Industrial Waste	86 (46.5%)	99 (53.5%)
Food Waste	177 (96.2%)	7 (3.8%)
Agricultural Waste	175 (94.6%)	10 (5.4%)
Biomedical Waste	71 (38.6%)	113 (61.4%)
Waste Tires	171 (92.4%)	14 (7.6%)

Majority of the respondents (87.5%) reported the presence of construction waste in their area, while 12.5% did not observe this type of waste. Electronic waste was noted by 55.1% of respondents, with 44.9% stating that it is not found in their locality. 46.5% of the respondents mentioned the presence of industrial waste, while a slight majority (53.5%) did not encounter it. Food waste was observed by a vast majority (96.2%) of the respondents, with only 3.8% reporting its absence. Similarly, agricultural waste was reported by 94.6% of the respondents, while 5.4% did not find it in their area. Biomedical waste was noted by 38.6% of respondents, whereas 61.4% did not report its presence. Waste tires were reported by a high percentage (92.4%) of respondents, with only 7.6% indicating they did not observe this type of waste.

In summary the data revealed that food waste and agricultural waste were the most commonly reported types of solid waste in Kiharu, Murang’a. Construction waste, biomedical and industrial wastes were also reported in Kiharu Sub-County. The findings agree with those by UNEP (2020) and FAO (2019), which reported that there is high organic waste in low-income areas. Aliaradan and Perrson (2012) indicated that the construction waste was as a result of the ongoing urbanization while the E-waste and industrial waste resulted from the rising tech use and small-scale industries. Biomedical waste and waste tires point to health service expansion and transport activity, consistent with WHO (2018) and UNEP (2021).

Solid Waste Management practices

This section summarizes the respondent’s opinions on various waste management practices on a scale from Strongly Disagree (SD) to Strongly Agree (SA). The results were presented in Table 4.5.

Table 4.5: Waste management practices

	SD %	D %	N %	A %	SA %	Mean	Std. Dev
Open landfills and open burning							
The use of open landfills is a common method for managing waste in Kiharu Sub-County.	7.5	14.0	6.5	48.4	23.7	3.67	1.198
Open landfills contribute significantly to environmental pollution in our community	1.6	6.5	9.1	63.4	19.4	3.92	0.828
Open burning is a common practice for waste disposal in my area.	0.5	3.8	14.0	58.1	23.7	4.01	0.760
Open burning of waste has a negative impact on air quality in Kiharu Sub-County.	1.6	0.0	9.2	60.0	29.2	4.15	0.714
Recycling and Re-use							
Recycling programs are effective methods for waste management.	4.9	7.6	16.8	53.3	17.4	3.71	1.003
I am willing to participate in recycling programs if they are made more accessible.	1.1	1.1	16.8	55.7	25.4	4.03	0.751
Re-using items is an effective way to reduce waste in our community	1.6	2.7	17.9	59.2	18.5	3.90	0.783
I actively look for ways to re-use items instead of disposing of them.	0.5	2.7	12.4	59.7	24.7	4.05	0.726
Composting and energy recovery							
Composting organic waste is a beneficial practice for managing household waste.	1.6	8.1	12.4	63.8	14.1	3.81	0.837
I would be interested in composting my household waste if resources were available	1.1	2.7	14.6	61.1	20.5	3.97	0.748
Converting waste to energy is a viable option for waste management in Kiharu Sub-County.	1.6	4.3	10.8	57.3	25.9	4.02	0.831
I support initiatives to recover energy from waste as a part of our waste management strategy.	0.5	3.2	10.3	59.5	26.5	4.08	0.736
Avoidance and Waste Minimization							
Waste avoidance and minimization should be prioritized over other waste management practices.	1.1	1.6	12.4	57.8	27.0	4.08	0.744
I make conscious efforts to minimize the amount of waste my household produces.	0.0	0.5	14.1	58.4	27.0	4.12	0.649

Notes: SD=Strongly Disagree, D = Disagree, N=Neutral, A = Agree, SA=Strongly Agree

Open landfills emerged as a common waste management method, with 48.4% of respondents agreeing and 23.7% strongly agreeing on its prevalence (M=3.67, SD=1.198). This method was significantly linked to environmental pollution, as 63.4% agreed and 19.4% strongly agreed. Open burning was also a common waste management practice (M=4.01, SD=0.760), with 58.1% agreeing and 23.7% strongly agreeing. This practice was found to negatively impact air quality, with 60.0% agreement and 29.2%.

Recycling and re-use practices were positively viewed as waste management practices, with 53.3% agreeing and 17.4% strongly agreeing that recycling programs were effective. Respondents showed a notable willingness to participate in accessible recycling programs, with 55.7% agreement and 25.4% strong agreement. Re-using items was also seen as effective (M=3.90, SD=0.783). Many said that they actively sought ways to re-use items, with 59.7% agreeing and 24.7% strongly agreeing.

Composting and energy recovery were viewed as beneficial waste management practices. Most people considered composting organic waste advantageous (M=3.81, SD=0.837). There was significant interest in composting if resources were available, with 61.1% agreement and 20.5% strong agreement. Waste-to-energy conversion was seen as viable (M=4.02, SD= 0.831). Support for energy recovery initiatives was strong, with 59.5% agreeing and 26.5% strongly agreeing. Lastly, waste avoidance and minimization were prioritized, with 57.8% agreeing and 27.0% strongly agreeing. Many respondents made efforts to minimize household waste (M=4.12, SD=0.649).

The findings were found to align closely with existing literature when it comes to waste handling in low- and middle-income countries. The widespread use of open landfills and open burning, as reported by the majority of respondents, is consistent with studies by Kaza *et al*. (2018) and UNEP (2020), which highlight that in Sub-Saharan Africa, more than 60% of waste is disposed of in uncontrolled dumpsites or burned in open spaces, leading to severe air, soil, and water pollution. These methods persist due to lack of infrastructure and weak enforcement of environmental regulations. On the other hand, the positive attitudes toward recycling, re-use, composting, and waste-to-energy practices reflect growing awareness of sustainable alternatives. Similar trends were reported by UN-Habitat (2018) and Balde *et al*. (2020), which found that communities are increasingly willing to engage in waste separation and recycling when such systems are made accessible. The strong support for waste avoidance and minimization further mirrors global shifts toward sustainable consumption, as promoted in the UN Sustainable Development Goals (SDG 12). These findings demonstrated both the challenges and the potential for transforming waste management in semi-urban areas like Kiharu through improved infrastructure and public engagement.

The importance of proper waste management practices

The respondents were asked to state the importance of proper waste management practices. The results were indicated in Table 4.6.

Table 4.6: The importance of proper waste management practices

	Yes %	No %
Its protects the environment	183 (100.0%)	0 (0.0%)
Recycling helps you to get money	114 (62.6%)	68 (37.4%)
It prevents water, air and soil pollution	176 (96.2%)	7 (3.8%)
Reusing conserves the resources	167 (91.8%)	15 (8.2%)

In Table 4.6, the respondents expressed their views on various benefits of effective waste management, revealing a strong awareness of its environmental and economic advantages. A unanimous consensus was reached regarding the role of waste management in environmental protection, with 100% of respondents agreeing that proper waste management practices protect the environment. The economic benefit of recycling was also acknowledged, with 62.6% of respondents agreeing that recycling helps generate income, while 37.4% did not see this benefit. This suggests that while a majority recognize the monetary gains from recycling, there is still a significant portion of the population that may not be fully aware of or able to access these benefits. Preventing pollution was another critical aspect highlighted by the respondents. A substantial 96.2% agreed that proper waste management prevents water, air, and soil pollution, with only 3.8% dissenting. This strong agreement reflects a widespread understanding of the health and environmental hazards posed by improper waste disposal. Reusing items to conserve resources was seen as important by 91.8% of respondents, while 8.2% did not agree. The high percentage of agreement indicates a community inclination towards sustainable practices that minimize waste and conserve natural resources.

The survey findings agree with past literature. For instance, the unanimous agreement among respondents on the environmental benefits of waste management is supported by a study by Wilson *et al*. (2018), which highlights that effective waste management is critical for reducing environmental pollution. The economic benefits of recycling are consistent with findings by Singh *et al*. (2018), who noted that recycling and re-use of wastes can generate significant income, especially in urban areas. The strong consensus on the role of waste management in preventing pollution corroborated with findings of a research by Tiseo (2019), which found that proper waste disposal practices significantly mitigate air, water, and soil pollution. Additionally, the recognition of resource conservation through reuse, as indicated by 91.8% of respondents, aligns with the study by Ellen MacArthur Foundation (2019), which emphasizes the importance of a circular economy in conserving resources. Finally, the agreement on preserving landfill space through proper waste management, supported by 92.3% of respondents, is corroborated by a report from the World Bank (2018) that underscores the necessity of reducing landfill use through waste minimization and recycling initiatives. These recent studies validate the survey results, highlighting the multifaceted benefits of proper waste management practices.

Table 4.7: Overall satisfaction on solid waste management practices

	Frequency	Percent	Cumulative Percent
Very Dissatisfied	37	20.1	20.1
Dissatisfied	58	31.5	51.6
Neutral	46	25.0	76.6
Satisfied	10	5.4	82.1
Very Satisfied	33	17.9	100.0
Total	184	100.0	

The findings in Table 4.7 gave a mixed sentiments regarding current waste management practices. A significant portion of respondents expressed dissatisfaction, with over half reporting either being very dissatisfied (20.1%) or dissatisfied (31.5%). About a quarter were neutral (25.0%), indicating a lack of strong opinion, while a smaller percentage reported satisfaction (5.4%) or very satisfaction (17.9%).

Table 4.8 Suggested ways for waste management in Kiharu Sub-County

Improvement Suggestion	Frequency	Percent
Recycling and reusing	21	28.0%
Regular garbage collection and proper disposal	14	18.7%
Government intervention and policy changes	15	20.0%
Employ more workers/personnel	14	18.7%
Creating awareness on waste management	11	14.7%
Total	75	100.0%

The results in Table 4.8 shows that most respondents, 28%, suggested that one of the ways to improve waste management is by enhancing recycling and reusing initiatives. Also, 18.7% of the respondents emphasized the need for regular garbage collection and proper disposal while 20% of the respondents called for government intervention and policy changes for regulatory improvements. Another 18.7% of the respondents suggested employing more workers or personnel to bolster waste management efforts. Lastly, 14.7% stressed the importance of creating awareness on waste management, indicating a need for educational campaigns to promote community involvement and understanding.

4.4.2 Key components of solid waste management systems in Kiharu Sub-County

Application of Waste Management Systems

The respondents were asked to express their opinion on whether the following waste management systems were applied in their area on a scale of 1 to 5 (1 = Not Applied, 5 = Highly Applied). The findings were presented in Table 4.9.

Table 4.9: Application of components of Waste Management Systems

	Not Applied %	Rarely Applied %	Occasionally applied %	Frequently Applied %	Highly Applied %	Mean	Std. dev
Collection	6.5	12.5	12.5	48.9	19.6	3.63	1.129
Transportation	5.5	12.1	17.6	44.0	20.9	3.63	1.109
Disposal	4.4	8.2	23.5	47.0	16.9	3.64	1.001
Reusing	13.0	40.5	19.5	23.2	3.8	2.64	1.090
Recycling	20.5	42.7	17.3	14.6	4.9	2.41	1.115

The findings indicated that basic waste management systems such as collection, transportation, and disposal were more frequently applied. However, practices like reusing and recycling were less implemented and applied. The frequent application of basic waste management systems like collection (M=3.63), transportation (M=3.63), and disposal (M=3.64) contrasts sharply with the limited adoption of reuse (M=2.64) and recycling (M=2.41) practices. This pattern aligns with Othoo *et al*.'s (2023) findings in Kenyan peri-urban areas, where infrastructure for basic waste services was more established than circular economy approaches. The low adoption rates for recycling (only 14.6% reporting frequent use) mirror challenges documented by Mwanthi *et al*. (2022), who identified lack of facilities, public awareness, and economic incentives as key barriers in similar East African contexts. These findings support Kiharu's need for targeted interventions to bridge this implementation gap, particularly through education programs and policy measures that incentivize sustainable practices, as recommended by UNEP's (2021) guidelines for developing nations. The standard deviation values (ranging from 1.001 for disposal to 1.129 for collection) indicate relatively consistent responses about basic services, while higher variation in recycling responses (SD=1.115) suggests uneven community engagement with these practices, a phenomenon also observed by Cherotich *et al*. (2020) in their study of Kenyan waste management behaviors.

Effectiveness of components of Waste Management Systems

The respondents were asked to express their opinion on whether the following waste management systems were applied in their area on a scale of 1 to 5 (1 = Not Effective, 5 = Highly Effective). The findings were presented in Table 4.10.

Table 4.10: Effectiveness of Waste Management Systems

	Not Effective %	Slightly Effective %	Moderately effective %	Effective %	Highly Effective %	Mean	Std. dev
Collection	3.2	7.0	15.6	39.8	34.4	3.95	1.036
Transportation	4.9	19.0	10.9	41.3	23.9	3.60	1.183
Disposal	5.4	11.4	23.8	42.7	16.8	3.54	1.068
Reusing	9.2	7.6	8.6	37.8	36.8	3.85	1.253
Recycling	9.2	6.5	7.1	37.0	40.2	3.92	1.252

From the findings in Table 4.10, waste collection was perceived to be functioning well and effective (M=3.95, SD=1.036) with most respondents (39.8%) finding it effective, and 34.4% rating it as highly effective. This aligns with Othoo *et al*.'s (2023) findings that primary waste collection systems in Kenyan peri-urban areas often receive higher community satisfaction ratings due to established municipal services. Similarly, most respondents indicated that recycling practices (M=3.92, SD=1.252) were effective, reflecting growing community confidence in recycling initiatives, a trend also observed in Nairobi's informal settlements by Mwanthi *et al*. (2022). These results suggest that further investments in recycling infrastructure and programs could be beneficial, as recommended in UNEP's (2021) waste management guidelines for developing nations.

The results also suggested that waste transportation (M=3.60, SD=1.183) and disposal (M=3.54, SD=1.068) were less effective compared to waste collection and recycling initiatives. This performance gap mirrors challenges identified by the World Bank (2022) in their diagnostic report on Kenya's waste management systems, particularly regarding intermediate and final waste handling. These results indicated that while collection and recycling were considered most effective practices, there was also significant room for improvement in waste transportation and disposal, as well as increased promotion and support for reusing waste materials - an area where Cherotich *et al*. (2020) found community engagement programs could yield substantial benefits.

4.4.3 Challenges of effective waste management practices

This section shows the challenges of effective waste management as indicated by the study respondents. The findings were presented in Table 4.11.

Table 4.11: Challenges of effective waste management practices

	SD %	D %	N %	A %	SA %	Mean	Std.dev
Dump sites are controlled by cartels	8.6	23.2	20.0	37.3	10.8	3.18	1.165
Process is not always cost-effective	9.1	18.8	19.9	47.3	4.8	3.20	1.090
Resultant product has a short life	7.6	41.3	21.2	23.9	6.0	2.79	1.077
Sites are often dangerous	4.3	10.9	20.7	45.7	18.5	3.63	1.042
Practices are not done uniformly	4.9	15.8	15.8	50.3	13.1	3.51	1.063
Waste management can cause more health problems	29.2	23.2	16.8	23.8	7.0	2.56	1.318
Lack of modern waste handling equipment	0.0	6.6	16.5	62.6	14.3	3.85	.742
Inadequate Personnel	3.3	10.4	15.9	53.8	16.5	3.70	.976

Notes: SD=Strongly Disagree, D = Disagree, N=Neutral, A = Agree, SA=Strongly Agree

From the findings in Table 4.11, one of the major challenges to effective waste management in Kiharu was lack of modern waste handling equipment (M=3.85, SD=0.742) followed by inadequate personnel (M=3.70, SD=0.976). The equipment deficit aligns precisely with Murang'a County's own 2022 assessment report, which noted only 32% of waste management stations possessed basic compactors or protective gear. The personnel challenges corroborate findings by Karanja and Ngugi (2023), whose study of Central Kenyan counties revealed an average 1:4,500 staff-to-resident ratio in waste services - far below WHO recommended standards.

Most respondents, 45.7% also agreed that waste management sites were often dangerous (M=3.63, SD=1.042) which indicated serious concerns about safety of the residents around these sites. This mirrored an alarming data from the Nairobi Waste Audit (NEMA, 2023) showing 61% of dump sites lacked proper fencing or hazard signage. Another main challenge was stated to be the inconsistency in waste management practices with more than half, 50.3%, agreeing that practices were not done uniformly. Although the respondents also pointed out health concerns and control of dump sites by cartels (M=3.18, SD=1.165) as one of the challenges, there those who thought they were not great challenges since they were rated quite low. While cartel influence scored lower this still reflects Otieno's (2021) documented pattern of informal sector dominance in secondary waste markets. Most critically, the consistency issues validate UNEP's (2021) warning about Kenya's patchwork implementation of waste policies.

4.4.4 Environmental impacts of solid-waste management practices

The participants of this survey indicated the environmental impacts of solid waste disposal in Kiharu sub-county. The results were presented in Table 4.12.

Table 4.12: Environmental impacts of solid-waste management practices

	SD %	D %	N %	A %	SA %	Mean	Std.dev
The solid waste disposed in our area has affected the quality of soil.	3.8	11.3	15.6	41.9	27.4	3.78	1.085
Solid waste disposed has contributed to air pollution in our community.	0.0	4.8	18.3	46.8	30.1	4.02	.825
The solid waste disposed in our area has affected the quality of water sources such as rivers and streams.	1.1	4.3	18.4	45.4	30.8	4.01	.875
Waste disposal in our area is linked to health problems in our community	1.6	7.5	12.9	43.0	34.9	4.02	.964
Waste disposal in our area has brought harm to natural habitats (like forests or wetlands)	1.6	8.6	10.8	47.0	31.9	3.99	.961

Note: SD=Strongly Disagree, D = Disagree, N=Neutral, A = Agree, SA=Strongly Agree

From the study findings, majority of the participants agreed that waste disposal has negatively affected soil quality (M=3.78, SD=1.085). The respondents also pointed out that the waste disposed in their area polluted the air as evidenced by a high mean rating of 4.02, with 46.2% of the respondents attributing air pollution in the community to improper waste disposal practices. The study findings also showed that water quality in local rivers and streams was similarly impacted (M=4.01, SD=0.875). In addition to environmental degradation, the community expressed concerns about health problems linked to waste disposal (M=4.02, SD=0.964). This shows that there was health risks associated with current waste management practices in Kiharu sub-county. Again, the harm to natural habitats, including forests and wetlands, was noted, with a mean rating of 3.99 and a standard deviation of 0.961 which showed that waste disposed in the area brought damage to the natural habitats.

4.5 Correlation Analysis

The study conducted a Pearson correlation analysis examine a linear association between solid waste management practices, components of waste management systems and challenges and Environmental impact. The test helped in determining whether there was a relationship between each independent variable and the dependent variable, the strengths of association, and the direction of the relationship, whether positive or negative. The results are as indicated in the table below:

Table 4.13: Pearson's correlation analysis

		Solid Waste Management Practices	Components of Waste management systems	Challenges to effectiveness of waste management practices	Environmental Impact
Solid Waste Management Practices	Pearson Correlation	1	.018	-.065	**.397****
	Sig. (2-tailed)		.819	.410	**.000**
	N		166	165	**175**
Components of Waste management systems	Pearson Correlation		1	-.030	**.202****
	Sig. (2-tailed)			.706	**.007**
	N			162	**174**
Challenges to effectiveness of waste management practices	Pearson Correlation			1	**-.167***
	Sig. (2-tailed)				**.029**
	N				**171**
Environmental Impact	Pearson Correlation				**1**
	Sig. (2-tailed)				
	N				

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

From the results, solid waste management practices had a moderate positive and significant relationship with the environmental impact, r=0.397, p<0.001. Notably, waste management systems in Kiharu had a positive and significant relationship with environmental impact, r=0.202, p=0.007. However, the challenges to effectiveness of waste management practices had a significant and negative relationship with environmental impact, r=-0.167, p=0.029. The findings suggest that practicing waste management in Kiharu and effective application of the management systems would result to better environment that is unpolluted. However, the challenges experienced brings a negative impact on the environment.

These results of align with existing researches about the relationship between waste management practices and environmental impact. For instance, research by Guerrero, Maas, and Hogland (2013) highlights that the implementation of proper waste management systems, such as waste segregation, recycling, and efficient collection methods, significantly reduces the ecological footprint of urban areas. These practices contribute to lowering the levels of pollution, reducing greenhouse gas emissions, and conserving natural resources. The negative association between the challenges to the effectiveness of waste management practices and environmental impact is supported by research from Ogwueleka (2009), which points out that barriers such as inadequate infrastructure, lack of funding, political interference, and insufficient public awareness can severely undermine waste management efforts. These challenges can lead to improper disposal practices, increased pollution, and health hazards, as observed in Kiharu. Furthermore, a study by Henry, Yongsheng, and Jun (2006) emphasized that without addressing the systemic and operational challenges in waste management, any positive environmental impacts are likely to be diminished or negated.

The findings were further illustrated using scatter diagrams.

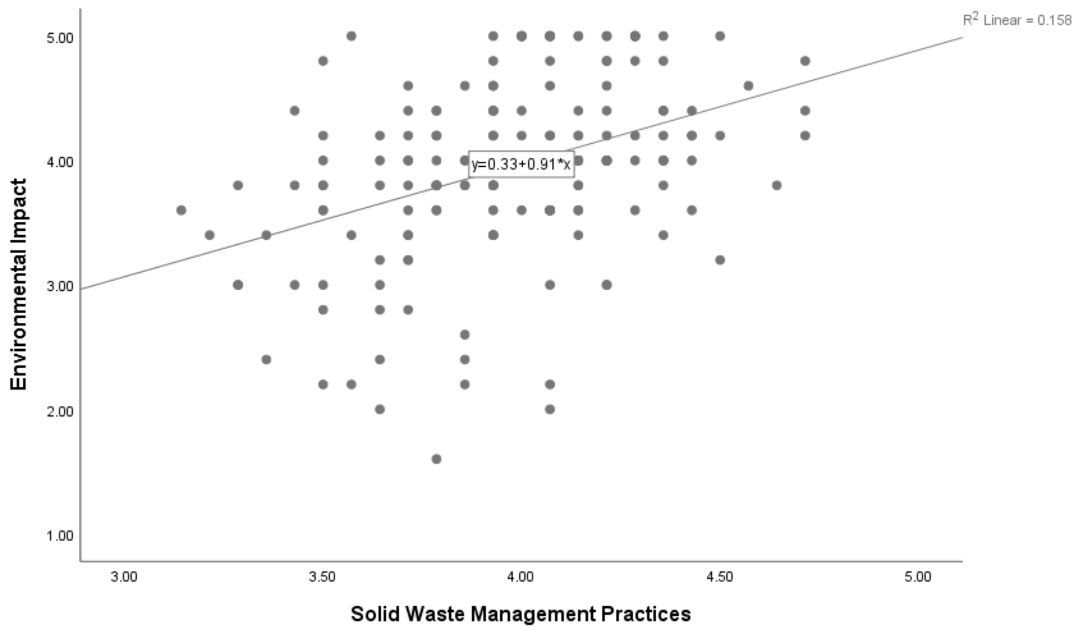

Figure 4.1: Scatter plot for waste management practices and environmental impact

Figure 4.1 shows there was a positive relationship between waste management practices and environmental impact. This implied that the better the waste management practices in place, the more and positive the impact on the environment is.

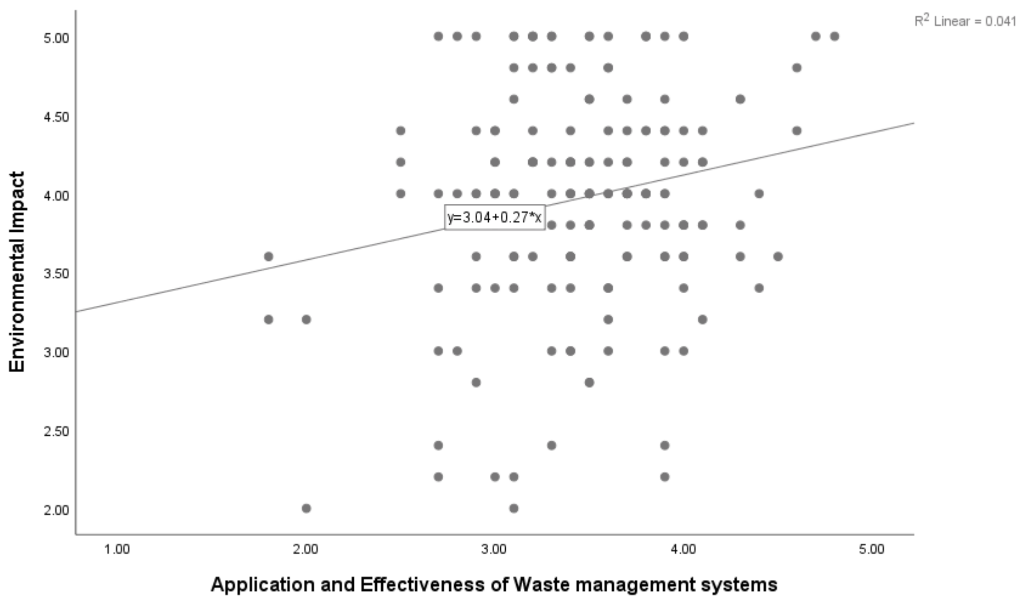

Figure 4.2: Scatter plot for waste management systems and environmental impact

Figure 4.2 shows there was a positive relationship between waste management systems and environmental impact. This implied that the better the waste management systems in place, the more and positive the impact on the environment is.

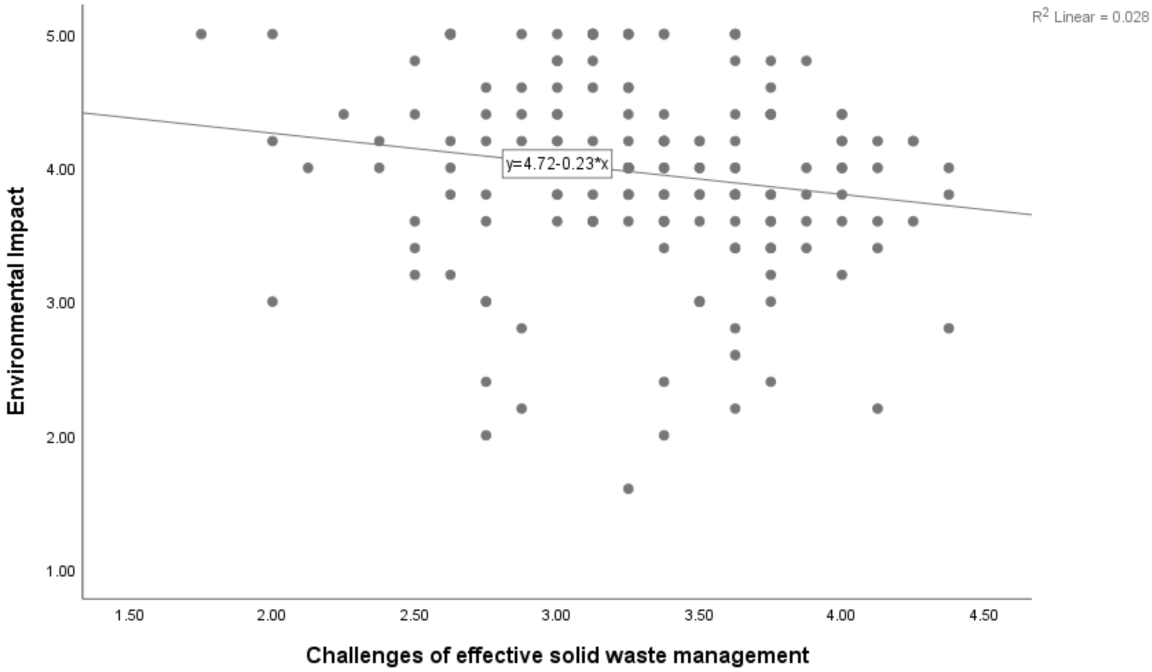

Figure 4.3: Scatter plot for challenges of effective waste management and environmental impact

Figure 4.3 shows there was a negative relationship between challenges of effective waste management practices and environmental impact. This implied that the more the challenges experienced, the more the negative impact on the environment.

4.6 Regression between the Impact of waste management practices, components of waste management systems and challenges on the environment

A multiple linear regression was performed with waste management practices, components of waste management systems and challenges of effective waste management as the independent variables and the Environmental impact as the response or dependent variable. This was aimed at assessing the environmental impacts of solid waste management in Kiharu Sub-County, Murang'a County, Kenya. The results were presented in three tables, model summary, ANOVA and model coefficients tables.

The model summary provided the correlation value (*R*=0.436) which indicated that there was a moderate correlation between the predictors (challenges to the effectiveness of waste management practices, waste management systems, and solid waste management practices and the dependent variable (environmental impact). The coefficient of determination (R^2=0.190) suggested that 19.0% of the variance or change occurring in environmental impact could be explained by the model.

Table 4.14: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.436[a]	.190	.174	.63664

a. Predictors: (Constant), Challenges to effectiveness of waste management practices, components of Waste management systems, Solid Waste Management Practices

Table 4.15 was an ANOVA table which showed the model significance.

Table 4.15: ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	14.194	3	4.731	11.673	.000[b]
	Residual	60.392	149	.405		
	Total	74.586	152			

a. Dependent Variable: Environmental Impact

b. Predictors: (Constant), Challenges to effectiveness of waste management practices, Application and effectiveness of Waste management systems, Solid Waste Management Practices

The ANOVA results in Table shows significance of the combined model in predicting the environmental impact using waste management practices and waste management systems. The results show that the model was significant in predicting environmental impact as the p-value associated with the F-value was statistically significant ($p<0.05$) at 5% level of significance, F=11.673, p<0.001.

Table 4.16 shows the findings of the model coefficients.

Table 4.16: Model Coefficients

Model		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	.666	.827		.806	.422
	Solid Waste Management Practices	.799	.165	.357	4.836	.000
	Components of Waste management systems	.236	.098	.177	2.403	.018
	Challenges to effectiveness of waste management practices	-.212	.099	-.157	-2.131	.035

a. Dependent Variable: Environmental Impact

From Table 4.17, the regression model was as follows:

$Y = 0.666 + 0.799X_1 + 0.236X_2 – 0.212X_3$

Where:

Y =environmental impact

X_1 = Solid Waste Management Practices

X_2 = Components Waste Management Systems

X_3 = Challenges to effectiveness of waste management practices

From the model, the association between solid waste management practices and the environmental impact was found to be significant and positive, $\beta = 0.799$, t=4.836, $p < 0.001$. This means that waste management practices impacted the environment greatly. In addition, the findings indicate that a unit increase in the waste management practices betters or increases the environmental impact by 0.799units.

Additionally, the association between the application and effectiveness of components waste management systems and the environmental impact was found to be significant and positive, $\beta = 0.236$, t=2.403, $p = 0.018$. This means that the application and effectiveness of waste management systems impacted the environment greatly. In addition, the findings indicate that a unit increase in the application and effectiveness of waste management systems betters or increases the environmental impact by 0.236 units.

Lastly, the association between the challenges of waste management practices and the environmental impact was found to be significant and negative, β = -0.212, t=-2.131, p = 0.035. This means that the challenges of waste management practices experienced impacted the environment in a negative manner. In addition, the findings indicate that a unit increase in the challenges worsens or decreases the environmental impact by 0.212 units. This means when there are challenges in the waste management practices, wastes are not well managed therefore leading to pollution, health problems and harm to natural habitats like forests and wetlands.

4.7 Discussion

The study sought to assess the environmental impacts solid waste management in Kiharu Sub-County, Murang'a County, Kenya. More specifically, the study looked at waste management practices, application and effectiveness of waste management systems and the challenges experienced during waste management practices and how they impacted the environment.

The study established that there was significant and positive association between solid waste management practices and the environmental impact. The findings indicated that if the wastes generated by humans such as construction wastes, chemical wastes, food wastes among others were well managed through practices such as burning, open-landfills, recycling and re-using, waste minimization, composting among others would lead to a better environment that is clean and healthy. These findings agree with findings by Wang *et al*. (2020), who emphasized that effective waste management practices, such as recycling and proper disposal methods, are crucial for reducing environmental pollution and preserving natural resources. Similarly, Smith *et al*. (2018) opined that communities with well-established waste management systems experience lower levels of environmental degradation, supporting the positive impact observed in this study.

The study also established that there was a positive and significant association between the application and effectiveness of waste management systems and environmental impact. This suggested that effective application of waste management systems such as collection, transportation, disposal, reusing and recycling would positively impact the environment reducing pollution and preserving the natural habitats. The findings aligned to past studies for instance a research by Johnson *et al*. (2017), who demonstrated that improved application of waste management technologies and policies leads to better environmental outcomes, including reduced pollution and enhanced ecosystem health. Additionally, Lee *et al*. (2019) highlighted that regions implementing effective waste management systems observe positive environmental changes, affirming the findings of this study regarding the beneficial impact on environmental quality.

Lastly, the study revealed a significant and negative association between challenges in waste management practices and environmental impact. This indicated that the challenges associated with waste management practices such as lack of modern waste handling equipment, inadequate personnel, dumpsites being controlled by cartels, dangerous sites among others would lead to environmental degradation. The findings agree with those of Sharma *et al*. (2019) who noted that challenges in waste management intensify pollution levels and harm natural habitats.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter presents a summary of the major findings of the study, conclusions and makes recommendations. The study sought to assess the environmental Impacts of Solid Waste Management in Kiharu Sub-County, Murang'a County, Kenya. The dependent variable was environmental impact while the independent variables were the waste management practices, waste management systems and challenged faced during waste management practices. The summary has been done in line with the study objectives. The study conclusions were logically deducted from the analysis of the data and each recommendation emanate from the findings and conclusions. This chapter finally suggested areas of further research while shedding light on the key areas which need more research to be conducted.

5.2 Summary of findings

The overall objective of this study was to assess the environmental impacts of solid waste management. The study collected data and presented the study findings in chapter four in line with the study objectives. The results were compared with the findings of other researchers who did similar studies.

To meet the overall objective, the study adopted a cross-sectional research design with quantitative and qualitative data-collection procedures being used simultaneously. The study targeted all the 19,404 residents of Kiharu-sub-county who included residents, chiefs, business owners, church leaders, school principals, elected government representatives in the County, NEMA and NGO officers, County Council officers in charge of waste collection and disposal in Kiharu Sub- County. This population was used to derive the sample size of 200 respondents. A total of 186 responded translating to a 93.0% response rate which was sufficient for analysis. The study had three independent variables namely, waste management practices, application and effectiveness of waste management systems and the challenges experienced during waste management practices and one dependent variable which was environmental impact. The data was collected using a questionnaire containing both open-ended and closed questions. The collected data was entered and analyzed using SPSS version 27.0. Descriptive statistical analysis was then conducted where statistics such as mean, frequency, standard deviation and percentage were produced to summarize the collected information and the results were presented using figures and tables. Pearson's correlation and regression analysis were used under inferential analysis to examine the significance, strength and direction of the association between waste management and environmental impact.

5.2.1 Types of waste disposed and the general perception of environmental impact

The study findings identified solid wastes that were disposed in their area and classified them into food waste, agricultural waste, waste tires, chemical wastes and construction wastes which were the most common. Biomedical waste, industrial waste electronic and chemical waste although they were not very common in the area.

There was a general observation that the solid waste disposed in Kiharu Sub-county degraded the environment. This was so as it degraded the soil quality the area, contributed to air pollution, affected the quality of water sources such as streams and rivers. Also it was noted that the waste disposed harmed the natural habitats and was also linked to poor health of the community at large.

5.2.2 Solid Waste management practices and the Environmental impact

In Kiharu sub-county, there were diverse waste management practices that were in place with the common ones being waste avoidance and minimization, recycling and re-use of waste products. The study findings also acknowledged the benefits associated with proper waste management practices highlighting prevention of pollution and protecting the environment as the major one. However, despite the existence of waste management practices, the study established that there was a general overall dissatisfaction of how the waste was being managed necessitating the need to improve the waste management infrastructure.

The study through regression and correlation analysis established that there was moderate significant and positive association between solid waste management practices and the environmental impact. The findings emphasized that effective waste management practices were crucial for reducing environmental pollution and preserving natural resources.

5.2.3 Components of Solid Waste management systems and the Environmental impact

The study findings established that basic waste management systems such as collection, transportation, and disposal were more frequently applied in Kiharu area. However, practices like reusing and recycling were less implemented and applied despite the acknowledgement that collection and recycling were the most effective waste management systems.

From correlation and regression analysis findings, study also established that there was a positive and significant association between the application and effectiveness of waste management systems and environmental impact. This meant that effective application of waste management systems such as collection, transportation, disposal, reusing and recycling would positively impact the environment reducing pollution and preserving the natural habitats.

5.2.4 Challenges of effective waste management practices and Environmental impact

The study found that there were challenges while implementing waste management practices which as a results affected the environment. The main challenges were: lack of modern waste handling equipment, inadequate personnel, inconsistency in waste management practices, and dangerous sites. Other challenges were dumpsites being controlled by cartels, health problems resulting from the practices, the process is not cost-effective and that the resultant products have short life span.

From correlation and regression analysis findings, the study revealed a significant and negative association between challenges in waste management practices and environmental impact which indicated that the challenges associated with waste management practices such as lack of modern waste handling equipment, inadequate personnel, among others would impact the environment negatively leading to pollution and destruction of natural habitats.

5.3 Conclusion of the Study

The study found out that construction wastes, food wastes, electronic wastes, industrial, agricultural biomedical and waste tires were generated in Kiharu Sub-County. The study also concluded that the wastes disposed degraded the soil quality the area, contributed to air pollution, affected the quality of water sources such as streams and rivers, harmed the natural habitats and was also linked to poor health of the community at large.

The study also concluded that despite the presence of various waste management practices such as open-landfills, burning, waste avoidance, minimization, recycling, and re-use, there was a general dissatisfaction with the effectiveness of these practices. Solid waste management practices were found to be moderately and positively associated with the environmental impact. This indicated that proper waste management helped to prevent pollution of water, air and soil and reduces the release of harmful substances into the environment.

The study also concluded that waste management systems such as collection, recycling, re-using, disposal and transportation were essential for reducing pollution and conserving natural resources. The study concluded that their application and effectiveness were key to realizing the environmental impact. Effective application of waste management systems when increased led to increased environmental impact.

The study also concluded that challenges such as lack of modern waste handling equipment, inadequate personnel, inconsistency in practices, and control of dumpsites by cartels would negatively impact the environment. Challenges had a significant and negative association with environmental impact, where an increase in challenges of waste management practices would lead to increased pollution and destruction of natural habitats.

5.4 Recommendations

This study makes the following recommendations:

1. Since all construction, electronic, industrial, food, agricultural, biomedical and waste tires were generated in Kiharu Sub-County, it is recommended that recycling and re-use of the wastes be adopted. Recycling would include setting up recycling centers and conducting extensive community education on the importance and methods of recycling and reusing waste.
2. Additionally, composting initiatives should be encouraged at both household and community levels to manage organic waste efficiently, reduce reliance on landfills, and improve soil quality. Furthermore, public education campaigns should be launched to promote waste minimization techniques, such as reducing single-use plastics and adopting sustainable consumption habits.
3. The efficiency and coverage of waste collection and transportation services must be improved to ensure timely and proper waste disposal. Strengthening disposal methods through the development and implementation of better techniques, including sanitary landfills and incineration facilities, is also crucial for managing different types of waste effectively. To support reusing and recycling efforts, incentives and support mechanisms, such as subsidies or tax breaks for businesses and households that adopt sustainable practices, should be provided.
4. Addressing the challenges faced in waste management practices is essential for minimizing their negative environmental impact. Investment in modern waste handling equipment is necessary to enhance the efficiency and safety of waste management operations. Additionally, increasing the number of waste management personnel and providing them with ongoing training will ensure they are equipped with the latest knowledge and skills. Strict regulations and monitoring of dumpsites should be implemented to prevent control by cartels and to ensure that these sites are managed safely and effectively. Finally, public awareness campaigns should be conducted to educate the community on the importance of proper waste management and to encourage active participation in waste management programs.

By implementing these recommendations, Kiharu Sub-County—through its local government, the Department of Environment, and other relevant implementing agencies such as the National Environment Management Authority (NEMA) and community-based organizations—can enhance its waste management practices. This will contribute to a cleaner, healthier environment and significantly reduce pollution and environmental degradation.

5.5 Areas of Further Research

There is need for more research on the emerging new waste management practices i.e source reduction and waste to energy.

Research on simulation of solid waste management and its environment impact to lessen its more and uncontrollable future effects on human life as the population further increases increasing waste production.

More research is needed on the existing solid waste measures and their effectiveness to help in finding out modern and more effective methods to cope with ever growing sizes of garbage finding its way in the dumpsite.

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APPENDICES

Appendices I: Research Authorization Letter from Kenyatta University

KENYATTA UNIVERSITY
GRADUATE SCHOOL

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P.O. Box 43844, 00100
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Our Ref: N50/CE/20098/2021

DATE: 21st February, 2023

Director General,
National Commission for Science, Technology and Innovation
P.O. Box 30623-00100
NAIROBI

Dear Sir/Madam,

RE: RESEARCH AUTHORIZATION FOR PHOEBE KALELWA MURUNGA – REG. NO. N50/CE/20098/2021

I write to introduce **Phoebe Kalelwa Murunga** who is a Postgraduate Student of this University. The student is registered for M.Env. degree programme in the **Department Environmental Sciences and Education.**

Phoebe intends to conduct research for a M.Env. Project Proposal entitled, **"Environmental Impacts of Solid Waste Management Practices in Murang'a County, Kenya".**

Any assistance given will be highly appreciated.

Yours faithfully,

PROF. ELISHIBA KIMANI
EXECUTIVE DEAN, GRADUATE SCHOOL

JO/lmi

Appendices II: NACOSTI License

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