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SCHOOL OF ARCHITECTURE AND BUILT ENVIRONMENT

**MSC IN GEO-INFORMATION SCIENCE FOR ENVIRONMENT AND SUSTAINABLE
DEVELOPMENT**

**ASSESSING THE EFFECTIVENESS OF SOLID WASTE DISPOSAL TO URBAN
ENVIRONMENTAL MANAGEMENT. (A CASE STUDY OF BUTARE CELL, NGOMA
SECTOR, HUYE DISTRICT)**

*Thesis submitted to the University of Rwanda: College of Science and Technology in partial
fulfillment of the requirements for the award of the Degree of Master of Science in Geo-
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DECLARATION

I declare that this Thesis is my original work and has never been submitted or examined in any University as an academic requirement for any award.

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APPROVAL

It is hereby confirmed that this thesis entitled “*Assessing the effectiveness of solid waste disposal to urban environmental management. A case study of Butare cell, Ngoma sector, Huye district*” submitted by **BIZIMANA Alain** was assessed in relation to the fulfilment of the requirements for the award of the Degree of Master of Science in Geo-Information for Environment and Sustainable Development, in the School of Architecture and Built Environment.

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ABSTRACT

This study aims to evaluate the effectiveness of solid waste disposal in promoting urban environmental management in Butare cell, Ngoma sector, Huye district. With the acceleration of global urbanization, waste management has become crucial for maintaining environmental health and sustainability in cities. The research focuses on assessing the current waste disposal practices and their impact on the urban environment within the study area. The study employs a stratified random sampling approach to survey 100 residents from various income backgrounds. Multiple techniques, including literature review, questionnaire survey, and field observations, are utilized to gather the necessary information to achieve the study objectives. The data collection process involves surveys that evaluate waste disposal practices, environmental concerns, and resident satisfaction with waste management services. Stratification is employed to capture diverse experiences and perceptions regarding waste disposal. The key findings indicate that food scraps constitute the dominant waste type generated by 57% of households, and 49% of respondents in Butare cell have a high monthly income, which significantly impacts both environmental quality and resident satisfaction. Notably, residents from higher socioeconomic backgrounds report better waste disposal practices and higher satisfaction with services, while those from lower socioeconomic backgrounds express concerns about insufficient waste management and its negative environmental consequences. The study also identifies specific weaknesses in the waste disposal system, such as inadequate infrastructure and a lack of public awareness regarding sustainable practices. This research emphasizes the necessity for improved waste management strategies in Butare cell, with a focus on enhancing infrastructure, increasing public awareness, and ensuring equitable service provision across all socioeconomic groups. By addressing these areas, Butare cell can develop more effective and sustainable solid waste management practices, thereby improving urban environmental management and creating a healthier living environment for all residents.

Keywords: Solid Waste Management, Urban Environmental Management, Waste Disposal and Policy Framework.

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LIST OF ACRONYMS AND ABBREVIATIONS

DDP: District Development Plan

EICV: Integrated Household Living Conditions Survey

EPA: Environmental Protection Agency

GGGI: Global Green Growth Institute

GHG: Greenhouse Gases

GIS: Geographic Information System

GIZ: German Agency for International Cooperation

MININFRA: Ministry of Infrastructure

NISR: National Institute of Statistics Rwanda

NLA: National Land Authority

PIASS: Protestant Institute of Arts and Social Sciences

PPPs: Public Private Partnerships

REMA: Rwanda Environment Management Authority

RITL: Recycling Industries Tanzania Limited

SPSS: Statistical Package for Social Sciences

SWM: Solid Waste Management

TVET: Technical and Vocational Education and Training

UNEP: United Nations Environment Programme

WtE: Waste to Energy

CHAPTER ONE: GENERAL INTRODUCTION

1. Background

Solid waste management is a critical global challenge, particularly in urban areas experiencing rapid population growth and economic development. The increasing generation of waste, coupled with inadequate infrastructure and disposal practices, has led to severe environmental and public health issues worldwide (Victoire et al., 2020). The world produces billions of tons of waste annually, with a significant portion ending up in landfills or improperly disposed of. This has resulted in pollution of air, water, and soil, as well as the spread of diseases. Developing countries often bear the brunt of this crisis due to limited resources and infrastructure (Abubakar et al., 2022). Improper waste disposal contributes to climate change through the release of greenhouse gases, such as methane, from landfills. It also leads to land degradation, water pollution from leachate, and air pollution from burning waste. Additionally, it poses significant risks to biodiversity and ecosystem health (Z. Zhang et al., 2024).

Urbanization is accelerating globally, leading to substantial increases in waste production. Urban areas typically produce more waste per individual than rural areas due to increased consumption patterns and reliance on disposable products (X. Q. Zhang, 2020).

Urban environmental management focuses on balancing rapid urbanization with environmental protection. It involves the planning, development, and implementation of strategies to address urban environmental challenges such as pollution, waste management, and resource consumption (Abdeljawad & Nagy, 2021). Governments around the world have implemented various policies and regulations to address the solid waste challenge. These include waste reduction strategies, recycling programs, landfill management regulations, and public awareness campaigns. However, the effectiveness of these policies varies widely across countries and regions (Kumari & Raghubanshi, 2023a).

Efficient solid waste disposal minimizes costs, energy use, and environmental impact while maximizing resource recovery through recycling, composting, and waste-to-energy processes. High-income countries like Germany have leading waste management systems, with a focus on waste prevention and high recycling rates. For example, Germany has a recycling rate of over 66% and less than 1% of municipal waste is landfilled (Nelles et al., 2016). Middle-income countries

face challenges in achieving high efficiency due to limited resources, infrastructure, and technology. Despite this, some have made progress. For example, in Brazil, the recycling rate of solid waste is around 17%, with São Paulo implementing advanced waste collection and processing systems. Low-income countries generally experience lower efficiency due to a lack of infrastructure, investment, and technical expertise. In Sub-Saharan Africa, waste collection coverage is typically below 50%, and most waste is disposed of in uncontrolled dumpsites, contributing to environmental degradation and public health risks (Lino et al., 2023).

Rwanda generates an estimated annual volume of 1.5 million tonnes of solid waste, with organic waste comprising approximately 75% of this total (GIZ, 2024). According to the National Sanitation Policy Implementation Strategy of 2016, the objective is to achieve a 60% proper disposal rate for household waste by 2020, and further increase it to 80% by 2030. Furthermore, the government aims to attain a 30% recycling rate for non-organic solid waste by 2019/2020, progressing to 40% by 2029/2030 (Rajashekar et al., 2019).

Rwanda, a nation classified as low-income, has demonstrated notable advancements in enhancing the efficiency of waste management. Nonetheless, challenges persist in terms of waste collection. Notably, the coverage of waste collection has experienced significant improvement, particularly in Kigali, where approximately 80% of households are now reached (Rajashekar et al., 2019). Moreover, the recycling and resource recovery rate in Rwanda is estimated to range from 12% to 15%, which falls below the global average. Notably, the country possesses only a limited number of formal recycling facilities, with much of the recycling being carried out on an informal basis (GGGI, 2019).

Huye district has unique challenges in waste disposal. It is important to understand current waste management practices in Huye district for developing effective solutions (GGGI, 2019). However, there is a lack of specific research focusing on Huye District, Ngoma Sector, and Butare Cell. This study aims to assess the effectiveness of solid waste disposal practices on the urban environment. The research will examine the challenges, opportunities, and potential solutions to contribute to the development of sustainable waste management strategies for the region.

1.2. Problem statement

Solid waste is generated because of material use. Both consumption and waste management contribute to waste generation (Yoshida & Mitsuo, 2018). If not properly managed, the significant amount of waste produced can have a substantial impact on the environment and human health worldwide (Abubakar et al., 2022).

High-income countries generate about 34% of global waste, but are efficient in managing it, often exceeding recycling rates of 50%. In contrast, low-income countries generate approximately 9% of global waste, with most of it ending up in landfills or open dumps (World Bank, 2018). Rwanda generates 0.69 kg of waste per capita per day, which is lower than the global average of 0.74 kg. However, waste collection and disposal efficiency remain a challenge, especially in rural areas and secondary cities (Victoire et al., 2020).

Efficiency and environmental compliance are crucial for effective solid waste disposal and urban environmental management. High-income countries excel in these areas due to advanced technology, strong regulations, and substantial financial resources (Kumari & Raghubanshi, 2023b). Conversely, countries like Rwanda face challenges such as limited infrastructure, financial constraints, and enforcement issues. However, Rwanda's commitment to sustainability and environmental protection can lead to improvements in waste management systems and better urban environmental management in cities like Kigali and Huye (Rajashekar et al., 2019).

Huye District's population was 328,398 in 2012 and now stands at 381,900 per the national census in 2022. Among the 14 sectors in Huye district, Ngoma sector is the most populated, resulting in increased waste generation that strains the existing waste management infrastructure (Manirakiza et al., 2020). Approximately 55.8% of the population dispose of waste in nearby bushes or fields, higher than the national average of 46.5%, causing environmental and health concerns, pollution, and resource depletion (NLA, 2022).

Ngoma is the most urbanized sector of Huye District, with 88% of its population residing in urban areas in 2012 and 90.8% in 2022. The total population of Ngoma increased from 27,705 in 2012 to 35,578 in 2022, as per the Fifth Rwanda population and housing census. The main factors for the increasing population are natural growth, rural-urban migration, and economic factors. This growth has resulted in higher waste generation, straining current waste management infrastructure and practices (Manirakiza et al., 2020).

Ngoma Sector faces challenges in managing solid waste, including inadequate infrastructure such as limited waste collection points and insufficient transportation systems. Low levels of public awareness about waste segregation, recycling, and proper disposal also contribute to the problem. Additionally, a lack of strict enforcement of waste management laws and regulations leads to non-compliance and illegal dumping. These barriers collectively contribute to environmental pollution, public health risks, and aesthetic degradation in Huye District (GGGI, 2019).

This study aims to assess the effectiveness of solid waste disposal mechanisms in Ngoma Sector and their alignment with urban environmental management objectives. It will explore existing waste disposal methods, the regulatory and policy framework, and the role of stakeholders, including local authorities, private entities, and the community. The findings will identify gaps in the current system, offer insights into the challenges faced, and suggest potential strategies for improving solid waste disposal and enhancing urban environmental management in Ngoma Sector.

1.3. Research Objectives

1.3.1 Main Objective

The general objective of this research is to assess the environmental, social, and economic challenges of solid waste disposal management in Huye district, Ngoma sector and Butare cell.

1.3.2 Specific Objectives

To attain the general objective, this study will specifically:

- Identify the types of solid waste produced.
- Evaluate the efficiency and environmental compliance of current waste collection and disposal systems.
- Analyze the logistical, financial, and regulatory barriers to effective solid waste management.
- Propose scalable solutions to enhance the sustainability and efficiency of waste management practices.

1.4. Research Questions

The following research questions guided the study:

1. What types and sources of solid waste are most prevalent in Ngoma sector?
2. How effective are the current waste collection and disposal systems in terms of coverage, frequency, and compliance with health and environmental regulations?
3. What are the key environmental, social, and economic impacts of current waste management inefficiencies in Ngoma sector?
4. What specific, scalable interventions can be implemented to improve the efficiency and sustainability of waste management systems in Ngoma sector?

1.5. Research Matrix

Table 1: Compatibility research matrix

Specific Objective	Research Questions	Data Required	Technique for Data Collection	Processing
Identify the types of solid waste and their sources in Ngoma sector	What types and sources of solid waste are most prevalent in Ngoma sector?	Types and sources of waste	Observation, surveys	Content analysis, Mapping
Evaluate the current systems of waste collection and disposal for efficiency and compliance with environmental standards.	How effective are the current waste collection and disposal systems in terms of coverage, frequency, and compliance with health and environmental regulations?	Mapping with GIS, Data on collection and disposal systems	Interviews with waste collection companies, local authorities	Statistical analysis, content analysis,

Specific Objective	Research Questions	Data Required	Technique for Data Collection	Processing
Analyze challenges that hinder effective solid waste management, focusing on logistical, financial, and regulatory barriers.	What are the key environmental, social, and economic impacts of current waste management inefficiencies in Ngoma sector?	Problems experienced	Surveys, interviews	Thematic analysis
Propose and assess potential solutions to enhance the sustainability and efficiency of waste management practices.	What specific, scalable interventions can be implemented to improve the efficiency and sustainability of waste management systems in Ngoma sector?	Potential solutions	Surveys, interviews	Thematic analysis

Source: Author (2024)

1.4. Significance of Study

This research was initiated after observing persistent solid waste in open spaces, despite government efforts to make Huye and other towns waste-free. The author aimed to assess the main challenges hindering sustainable solid waste management, particularly in the Ngoma sector.

The study evaluates the effectiveness of Ngoma's solid waste management system in addressing urban environmental issues and proposes critical solutions. Sustainable waste management is essential for the sector's development, as ineffective practices lead to environmental degradation and health risks, such as climate change, groundwater contamination, and land degradation. This research aims to reinforce Ngoma’s role as a model for urbanization and environmental management in Huye district, emphasizing waste management as a key priority

1.6. Conceptual Framework

This research employs a conceptual framework that maps out the entire solid waste management process, from initial waste generation to final disposal. The framework highlights the interconnectedness of various stages, including storage, collection, transportation, processing, and disposal. This structured approach was used to evaluate the efficiency and environmental impact of Ngoma sector's waste management practices.

Solid waste management involves several key stages: i) Waste Generation: This is the initial stage where waste is produced by households, businesses, and institutions. ii) Waste Storage: This involves the temporary containment of waste at the point of generation, typically using bins or containers. iii) Waste Collection: This is the organized gathering of waste from storage points for transportation to processing or disposal facilities. iv) Waste Transportation: This involves the moving of collected waste from collection points to processing or disposal sites. v) Waste Processing: This includes the treatment of waste to reduce its volume, enhance resource recovery, or alter its properties for disposal. Examples include recycling, composting, and waste-to-energy conversion. vi) Waste Disposal: This refers to the final placement of waste in a landfill or other designated area. This slide details the six essential components of a solid waste management system. Each stage plays a crucial role in ensuring efficient and environmentally sound waste management.

We have used this framework to analyze Ngoma sector waste management practices. Our investigation covered waste generation patterns, storage methods, collection efficiency, transportation routes, and available processing and disposal facilities. By examining each stage, we aim to identify the system's strengths and weaknesses and their impact on environmental sustainability. This conceptual framework has guided our evaluation of Ngoma sector waste management system, allowing us to understand how waste is managed from generation to disposal. Through this analysis, we have pinpointed areas where the system works well and areas requiring improvement for a more sustainable environmental impact.

Environmental sustainability and waste management practices aim to minimize the negative impact of waste on the environment. This includes reducing waste generation at the source, recovering valuable resources through recycling and composting, and employing safe and

responsible disposal methods to minimize pollution. Environmental sustainability is a core objective of effective waste management. By examining Ngoma sector waste management practices through this framework, we can determine how effectively the system contributes to a clean and healthy environment. The goal is to minimize waste, maximize resource recovery, and safely dispose of remaining waste to protect the city's natural resources.

This conceptual framework provides a valuable tool for evaluating waste management practices in Ngoma sector. By systematically examining each component and its impact on environmental sustainability, we can gain valuable insights to guide future improvements. Ultimately, the goal is to recommend waste management strategies that are efficient, resource-conscious, and protective of the city's environment.

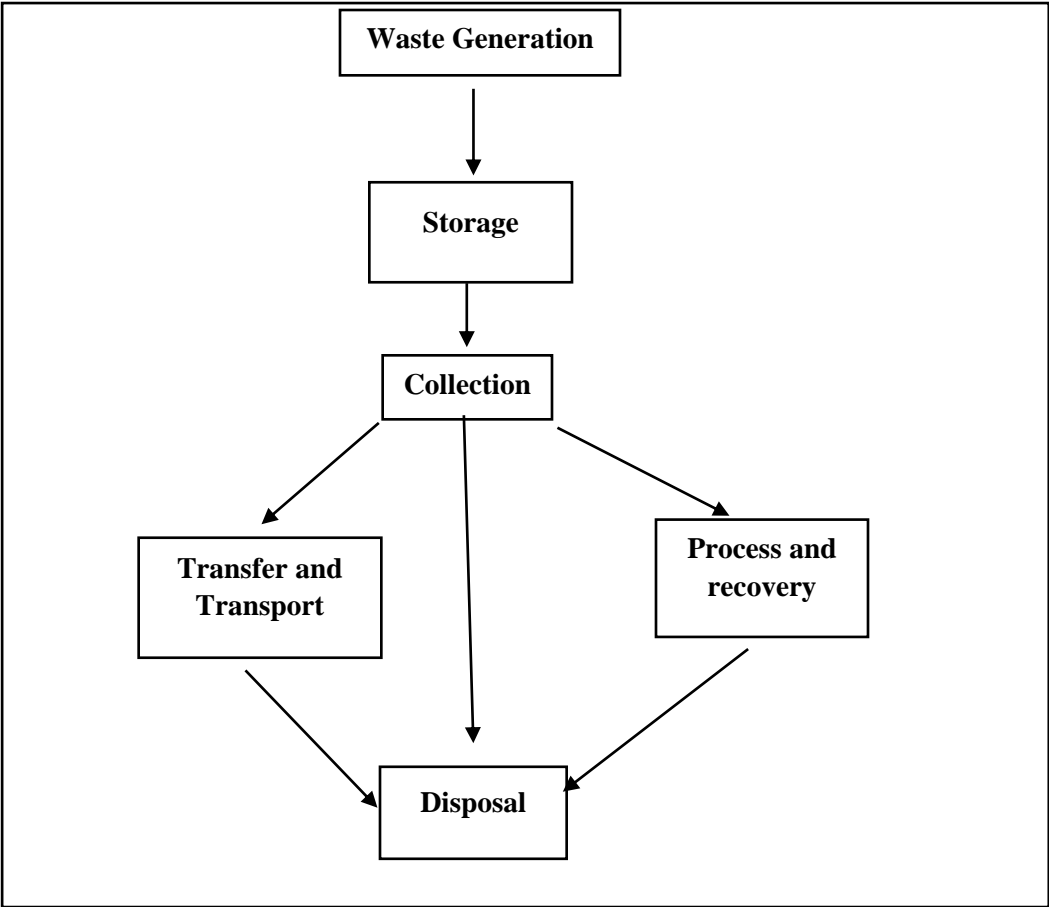


Figure 1: Interrelationship of a functional element comprising an SWM

Source: Author 2024

CHAPTER TWO: LITERATURE REVIEW

2.1. Introduction

This literature review explores various dimensions related to solid waste disposal and its impact on urban environmental management, with a specific focus on Butare cell. By synthesizing findings from published books, papers, theses, journals, and electronic sources, this chapter identifies key trends, challenges, and opportunities in the field.

2.2. Definition of the key concept and related literature

2.2.1 Urbanization

Urbanization, defined as the migration of populations from rural to urban areas, significantly influences waste generation. This process increases the volume of waste produced due to higher consumption levels and changes in lifestyle and consumption patterns. As cities develop, efficient waste management becomes crucial to mitigate environmental and health impacts (Gutu Sakketa, 2023).

2.2.2 Urban Environmental Management

Urban environmental management focuses on balancing rapid urbanization with environmental protection. It involves strategies to address challenges like pollution, waste management, and resource consumption within urban areas (Dodman et al., 2013).

2.2.3 Solid Waste Management

Solid waste management (SWM) encompasses the systematic control of waste generation, collection, storage, transportation, processing, treatment, and disposal. It aims to minimize waste's impact on human health and the environment while recovering resources (Gupta et al., 2024).

2.2.4 Effectiveness in Waste Management

Effectiveness in waste management refers to the degree to which a waste management system achieves its objectives, such as reducing environmental impacts, improving public health, and promoting sustainability. It involves assessing the performance of various components of the system, including collection, transportation, processing, and disposal (Pamela, n.d.).

2.2.5 Efficient Solid Waste Management

Efficient solid waste management focuses on optimizing resource utilization, minimizing costs, and maximizing the environmental benefits of waste management practices. This includes

implementing advanced technologies, improving collection and transportation systems, and promoting waste reduction and recycling (Khan et al., 2024).

2.3 Relationship between urbanization and waste generation

Urbanization leads to increased waste generation due to population growth, economic development, and lifestyle changes (Burke et al., 2012). As more people migrate to cities, the demand for goods and services rises, contributing to higher levels of consumption and waste production (Mcgranahan & Satterthwaite, 2014). In Butare Cell, rapid urbanization has resulted in higher waste production, posing challenges for existing waste management infrastructure. Studies show that urban areas typically generate more non-biodegradable and electronic waste compared to rural areas, necessitating advanced waste management strategies (MININFRA, 2022). Waste-to-energy technologies are also adopted in some urban areas, offering the potential to offset waste generation to some extent (World Energy Council, 2016). The way cities are planned and developed can influence waste generation patterns. Sustainable urban planning can incorporate waste reduction strategies and efficient waste management systems, thereby mitigating the environmental impact of urbanization (UNEP, 2016).

2.4. Convergence and divergence of theoretical frameworks

Effective waste management is crucial for protecting the environment, safeguarding public health, and driving economic growth. Theoretical frameworks provide valuable perspectives for understanding and addressing waste management issues. This literature review aims to fill this gap by exploring the benefits of integrating theoretical frameworks in understanding solid waste disposal methods.

❖ Theoretical frameworks in solid waste disposal

Integrated Sustainable Waste Management (ISWM) is a holistic approach that considers all stages of the waste management process, from generation to disposal. It emphasizes the importance of waste reduction, reuse, recycling, recovery, and disposal as a last resort. ISWM is particularly relevant for this study as it provides a comprehensive framework for analyzing the interconnections between different waste management activities and their impact on the environment (Wilson et al., 2013).

The waste management hierarchy prioritizes waste management options based on their environmental impact. It promotes waste prevention, reuse, recycling, recovery, and disposal as the least preferred option. This framework aligns with the principles of sustainable development and can be used to assess the effectiveness of different waste management strategies in Huye District. For the specific context of this study, the ISWM framework is more suitable. It provides a broader perspective on waste management, encompassing not only the technical aspects but also the social, economic, and environmental dimensions. By applying ISWM, the research can analyze the entire waste management system in Huye District, identify gaps, and propose improvements (Ferrari et al., 2016).

❖ **Qualitative and quantitative approaches**

Qualitative descriptions of waste management challenges shed light on the multifaceted nature of urban waste management problems. Factors such as inadequate infrastructure, limited financial resources, poor waste collection services, and inadequate regulatory frameworks contribute to the inefficiency of waste management systems (Kwakye et al., 2024). Additionally, community perceptions, cultural practices, and socioeconomic disparities influence waste disposal behaviors and attitudes toward waste management practices while qualitative studies provide valuable insights into the socio-cultural and institutional dimensions of waste management, quantitative research offers empirical evidence of the effectiveness of waste disposal practices. Studies evaluating the performance of waste management systems based on indicators such as waste diversion rates, recycling rates, landfill capacity, and environmental impact assessments provide quantitative data to assess the success and shortcomings of waste management strategies (Georgina & Beatriz, 2018).

2.6. Policy and regulatory framework analysis

Over the last seven years, Rwanda has strengthened its regulatory and policy frameworks concerning solid waste disposal and urban environmental management, particularly in response to rapid urbanization. The government's efforts are guided by various policies, laws, and regulations aimed at ensuring sustainable environmental management. The key regulatory framework is the National Environment and Climate Change Policy (2019), which emphasizes integrated waste

management, including reduction, recycling, and disposal practices, to protect the environment and public health. This policy aligns with the country's Vision 2050, which aims to promote green growth and climate resilience through effective waste management practices (MoE, 2017).

The National Sanitation Policy (2016) and its accompanying Implementation Strategy are crucial in shaping Rwanda's approach to urban waste management. This policy sets ambitious targets for waste disposal and recycling, including the goal of properly disposing of 80% of household waste by 2030. It provides a framework for municipalities, including Huye District, to improve waste collection services, promote waste segregation at source, and encourage community participation in waste management. The policy also supports the development of infrastructure such as sanitary landfills and recycling facilities, which are critical for managing solid waste in growing urban centers like Huye (MININFRA, 2023).

At the regulatory level, the Organic Law No. 04/2005 of 08/04/2005 concerning the protection, conservation, and promotion of the environment in Rwanda remains foundational. This law mandates that all activities, including waste management, must not compromise environmental sustainability. In recent years, this law has been supplemented by specific directives on waste management, such as the Ministerial Order No. 002/16.01 of 24/05/2016 which details regulations on solid waste management. This order outlines the responsibilities of local governments in managing waste and sets penalties for non-compliance, thus ensuring stricter adherence to waste management practices in districts like Huye (Government of Rwanda, 2016).

The Huye District DDS (2018-2024) prioritizes improving waste management systems as part of its broader goal of enhancing urban environmental management. This strategy emphasizes the need for better waste collection, the establishment of controlled disposal sites, and the enforcement of waste management regulations at the local level. By aligning district-level strategies with national policies, Huye District is working to address its unique waste management challenges, ensuring that solid waste disposal practices contribute effectively to urban environmental management (HUYE District, 2018). Rwanda's regulatory framework for waste management includes several policies aimed at improving waste collection and recycling, however in Ngoma sector, the enforcement of these policies remains weak. Detailed analysis reveals gaps in waste segregation guidelines and landfill management procedures. Future research should focus on evaluating the

effectiveness of these regulations and developing strategies to enhance compliance and enforcement (RoR, 2018).

2.7. Waste Management Practices and Strategies

Effective methods of solid waste disposal, including landfilling, incineration, and recycling, have distinct advantages and disadvantages. In Butare cell, the management of landfills is poor, resulting in environmental risks, while recycling efforts are limited due to inadequate infrastructure and public participation (UNEP, 2016). The implementation of waste-to-energy technologies could provide a sustainable solution; however, its feasibility depends on local conditions, such as waste composition and economic factors (Rezania et al., 2023).

Waste-to-Energy (WtE) shares similarities with incineration in terms of its benefits. WtE reduces waste volume and generates energy from waste, potentially being more efficient in energy production compared to traditional incineration. Nonetheless, it shares similar concerns as incineration regarding high costs, air pollution emissions, and ash disposal. The economic viability and environmental impact of WtE require careful feasibility studies. In the case of Huye, similar to incineration, WtE may not be a feasible option due to current resource limitations (Rahman & Alam, 2020).

While efforts have been made, challenges persist in achieving effective waste management strategies in Huye District. Inadequate waste disposal facilities, limited public awareness, and insufficient enforcement of waste management regulations have hindered progress. The district's waste management infrastructure, although improved, struggles to cope with the increasing volume of waste generated by the urban population. Further, the lack of comprehensive recycling facilities results in a significant portion of recyclable materials being either improperly disposed of or left unmanaged. Addressing these gaps, necessitates ongoing efforts to enhance infrastructure, strengthen policy enforcement, and increase community engagement in waste management practices (MININFRA, 2022).

2.8. Various waste management practices and strategies implemented in urban areas

In Pune, India, a mobile app was developed for citizens to report waste collection issues, track bin locations, and request special pickups. This initiative increased citizen engagement and improved service transparency. Creating a basic mobile app could be a cost-effective solution for Butare cell, allowing residents to report overflowing bins, request collection services, and access educational resources on waste management (Vishnu et al., 2021). To improve communication and transparency between residents and waste management services, Bogotá, Colombia, implemented digital platforms for managing waste. They created a mobile app that enables residents to schedule waste collection, report issues, and access information on waste. A simple SMS-based system could be feasible for Butare cell. Residents could send a text message with a specific code to report full bins or request collection, which would improve communication and service responsiveness (Herman, 2021). The waste management challenges in Ngoma sector can be tackled by using technological solutions that are suitable for its economic and infrastructural conditions. To begin with, implementing low-cost options such as smart sensors, manual sorting facilities, and community composting can be effective first steps. As the system develops, digital platforms like SMS-based communication can further enhance efficiency. By drawing insights into successful case studies and prioritizing viable technological solutions, the Ngoma sector can improve its waste management practices to become more sustainable and efficient.

2.9. Successful case studies and best practices in waste management in East Africa

The East African region has witnessed several successful case studies in waste management that provide valuable insights and best practices for enhancing urban environmental management. These case studies have been instrumental in informing the development of effective waste management mechanisms, including those suggested for implementation in Huye District. By examining these successes, it becomes possible to adapt and tailor strategies to local contexts, thereby improving the effectiveness of solid waste disposal and overall environmental health. One notable example is the waste management system in Kigali, Rwanda, which has been recognized as one of the cleanest cities in Africa. Kigali's success is largely attributed to its comprehensive waste collection system, stringent enforcement of waste disposal regulations, and active community participation. The city's approach involves regular waste collection services managed

through public-private partnerships, alongside robust awareness campaigns that encourage residents to segregate waste at the source. Moreover, Kigali has implemented strict penalties for illegal dumping, which has significantly reduced instances of improper waste disposal. These practices have not only kept the city clean but have also contributed to better public health outcomes (Rajashekar et al., 2019). Similarly, Mombasa, Kenya has made strides in waste management through the introduction of waste-to-energy projects. The city has collaborated with international partners to convert municipal solid waste into energy, providing a sustainable solution to both waste disposal and energy needs. This initiative has been particularly successful in reducing the amount of waste directed to landfills while generating electricity for local use. The success of Mombasa's waste-to-energy projects highlights the potential for similar approaches in other urban areas, including Huye District, where there is a need to manage increasing waste volumes more sustainably (UN-Habitat, 2019).

Inspired by these successful case studies, several mechanisms have been suggested for improving waste management in Huye District. These include the adoption of public-private partnerships for waste collection, the establishment of waste-to-energy facilities, and the enhancement of community education programs to promote waste segregation at the household level. Additionally, the implementation of stricter regulations and penalties for non-compliance, as seen in Kigali, could help to enforce better waste management practices. By drawing on these best practices, Huye District can develop a more effective and sustainable waste management system that addresses the unique challenges of urban environmental management (MININFRA, 2022).

2.10. Gaps in research and future directions

Despite the progress made in waste management practices in Huye District, there are still significant gaps in research that need to be addressed to fully understand and enhance the effectiveness of solid waste disposal. These gaps primarily pertain to the long-term sustainability of waste management practices, the socio-economic implications of waste disposal methods, and the integration of advanced technologies for improved waste management outcomes.

Limited research has been conducted on the long-term environmental and socio-economic sustainability of current waste disposal methods in Huye District. While immediate strategies such as waste collection and landfill management are in place, their long term effectiveness, particularly

in terms of environmental degradation and resource depletion, remains underexplored (REMA, 2021).

Future research should focus on conducting longitudinal studies to assess the environmental impacts of existing waste disposal methods over time. This includes analyzing the degradation rates of waste in landfills, the potential for groundwater contamination, and the effects on local biodiversity. Additionally, research could explore alternative waste management strategies, such as the development of sustainable landfills and the implementation of circular economy principles that promote waste minimization and resource recovery (UNEP, 2020).

Research should investigate the socio-economic dimensions of waste management, such as the health impacts of inadequate waste disposal, the economic opportunities lost due to inefficient waste management, and the social equity issues related to waste disposal in different communities. Studies could focus on identifying the disparities in waste management services across various income groups and exploring how these disparities impact overall community well-being (World Bank, 2018).

The application of advanced waste management technologies, such as waste-to-energy processes, recycling automation, and digital monitoring systems, has not been extensively explored in the context of Huye District. The district's waste management system primarily relies on traditional methods, which may not be sufficient to handle increasing waste volumes and the growing complexity of waste types.

Future research should explore the feasibility and potential benefits of integrating advanced technologies into Huye District's waste management system. This could include studies on the adoption of waste-to-energy technologies to reduce landfill waste, the implementation of smart waste collection systems to optimize waste collection routes, and the development of recycling infrastructure to increase recycling rates. Research could also focus on the barriers to technology adoption, such as cost, technical expertise, and community (Ambati, 2019).

CHAPTER THREE: DATA SOURCES AND METHODOLOGY

3.1. Study Area and description.

Huye District, located in Rwanda's Southern Province, spans 581.5 square kilometers and comprises fourteen sectors and 509 villages. With a population density of 540 inhabitants per square kilometer, it borders Nyanza, Gisagara, Nyaruguru, and Nyamagabe districts. The district's strategic location along the main road between Kigali and the Republic of Burundi facilitates significant economic activities, particularly in agriculture and manufacturing (HUYE District, 2018).

This study focuses on Ngoma Sector due to its rapid urbanization and significant population growth. Ngoma is the most urbanized sector, with 90.8% of its population residing in urban areas, housing many students from the three universities in Ngoma. These factors contribute to a significant increase in waste generation, making this area ideal for studying waste management practices and their environmental effects.

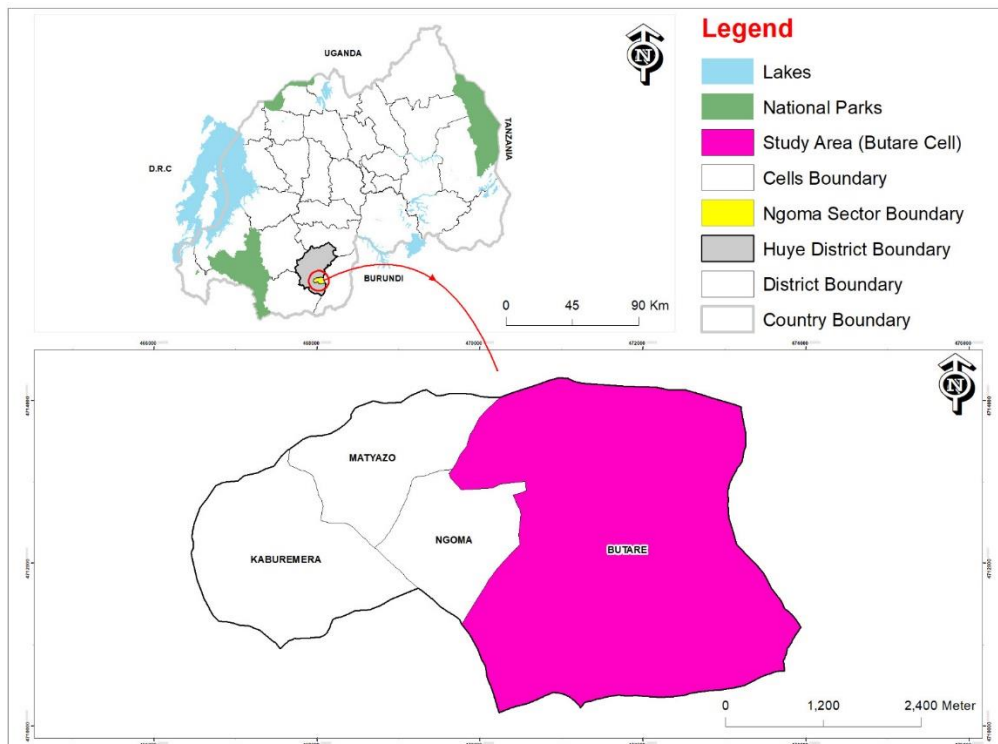


Figure 2: Location map of the study area

Source: NISR, 2012 (Author 2024)

Ngoma sector generates a diverse range of waste, including organic waste from households, food waste from businesses, construction debris, and electronic waste. Understanding the specific composition of this waste is crucial for developing effective waste management strategies. Butare cell relies on an uncontrolled dumpsite rather than a sanitary landfill. Additionally, waste collection services might be inefficient. Studying these limitations allows for the evaluation of the current system's effectiveness and environmental impact. Analyzing the existing policies and regulations related to waste management in Butare cell can reveal potential gaps or areas for improvement. This can provide recommendations for more robust and sustainable waste management practices.

While specific data on Ngoma Sector might be limited, here's why they can be significant for understanding Butare cell waste management challenges in the context of urbanization where Ngoma Sector might represent the urban area as Butare cell central core experience rapid population growth due to people migrating from rural areas seeking urban opportunities. This influx can strain waste collection services designed for a smaller population, leading to increased waste accumulation and potential environmental hazards in this sector. It might have a higher proportion of organic waste from households and commercial waste in the central area.

3.2 Data collection techniques

3.2.1 Secondary data

Secondary data provided insights into existing research on urban solid waste disposal and management, particularly in Rwanda and Butare cell. Sources included published books, scientific papers, dissertations, government policy documents, and reports. These were accessed from the University of Rwanda library and online databases. Simple statistical techniques like percentage and mean were used to analyze population growth and solid waste generation trends.

3.2.2 Primary Data Collection

Data collection for this study involved a combination of surveys, questionnaires, interviews, focus group discussions, site visits, and direct observations.

3.2.2.1 Field observation

Field observations involved on-site visits to waste disposal facilities, landfills, recycling centers, and waste collection points to document conditions, infrastructure, and operations. This helped assess the effectiveness of waste disposal methods.

3.2.2.2 Surveys and Questionnaires

The primary goal of the questionnaire and survey was to gather reliable data directly from respondents. This **Household survey** was conducted among households in the urban area of Butare cell and community surveys to collect data on waste generation, collection coverage, disposal methods, and perceptions of environmental impacts. Stratified sampling to conduct surveys with residents across different socio-economic backgrounds and housing types.

Household surveys were conducted among 100 households in Butare cell to gather data on waste generation, collection coverage, disposal methods, and perceptions of environmental impacts. Stratified sampling was used to ensure representation across different socio-economic backgrounds. Surveys aimed to collect accurate information from respondents, with stratified sampling ensuring comprehensive representation.

3.2.2.3 Sample size

A. Sample size and Sampling techniques

A stratified random sampling technique was employed to ensure that the sample was representative of the various socioeconomic groups within Huye District, Ngoma Sector, and Butare cell. The population was divided into strata based on household income levels: low-income, middle-income, and high-income households. Proportional allocation was used to determine the number of households sampled from each stratum.

The population consists of all households in Ngoma sector. The total number of households in the area is N where N=5,542 households and the sample size apply Cochran's formula for sample size determination. the study area was given a chance to every individual household, and it was used to Determine the sample size of households surveyed in Huye district:

$$n = \frac{N \times n_0}{N + n_0}$$

Where n is the sample size; N is the universe or total target population within the study area. In this study target population is represented by households and we have to deal with 5542 households; n_0 is the variant calculated from the probability of two complementary events p and q , where $p = q = 0.5$ - $p + q = 1$. this theory, Cochran (1963) has developed the equation which gives the value of n_0 as follows:

$$\frac{z^2 * p * q}{10^2}$$

z is the threshold of confidence which is estimated to be equal to 2 and e stroke of errors is estimated to 10% or 0.10. by here we can calculate the value of n_0 : $\frac{2^2 * 0.5 * 0.5}{0.10^2}$

the above result, No: $\frac{4 * 0.25}{0.01}$

No= 100

$n = \frac{5,542 * 100}{5,542 + 100} = 99.8 \sim 100$ Households these formulas as sample size,

Proportional allocation is used to determine how many households to sample from each stratum.

I am stratifying by income, let's denote:

- N_1 as the number of low-income households
- N_2 as the number of middle-income households
- N as the number of high-income households

The sample size for each stratum can be calculated using the formula:

$$n_i = \frac{N_i}{N} * n$$

Where:

- n_i is the sample size for stratum iii
- N_i is the population size of stratum iii
- N is the total population size
- n is the total sample size
- $N=5,542$ total households
- $N_1=1275$ low-income households
- $N_2=2715$ middle-income households
- $N_3=1552$ high-income households
- $n=100$ total households to be sampled

The sample sizes for each stratum would be:

$$n_1 = \frac{1275}{5542} \times 100 = 23 \quad \text{households from low-income stratum}$$

$$n_2 = \frac{2715}{5542} \times 100 = 48.9 \sim 49 \quad \text{households from middle-income stratum}$$

$$n_3 = \frac{1552}{5542} \times 100 = 28 \quad \text{households from high-income stratum}$$

The total population was estimated to be 5542 households, with 1275 classified as low-income, 2715 as middle-income, and 1552 as high-income. A sample size of 100 households was determined to be sufficient for the study, leading to 23 households sampled from the low-income stratum, 49 from the middle-income stratum, and 28 from the high-income stratum. Households were then randomly selected within each stratum to participate in the survey. Using stratified sampling ensures a more representative analysis of the waste management situation in Butare Cell. This data was crucial for developing effective solutions that address the diverse needs and challenges faced by different demographic groups within the city.

3.2.2.4 Geospatial Data Collection

Geographic Information System (GIS): Collect geospatial data to map waste disposal sites, infrastructure, and environmental features. GIS can help visualize the spatial relationships between waste management and the environment.

This was done in case of waste disposal data by recording information on waste disposal sites, their locations and usage trends and Geospatial Data in Collecting geographic data such as maps, satellite imagery, and aerial photos of Ngoma Sector, GIS tools to perform spatial analysis including spatial distribution of waste generation also route optimization for waste collection.

3.2.2.5 The interview

Interviews were conducted with local authorities responsible for environmental management and social affairs at Cell and Sector level, as well as with urban waste collectors. Interview questions were designed to gather detailed information on waste collection, transportation, and disposal methods. Stakeholders including GREENCARE RWANDA Ltd provide sustainable solution for solid waste management by converting landfilling into recycling plants, 3 waste collection companies such as COFAB, BUTARE CLEANERS Company, and PROFESSIONAL HYGIENE Company provided insights on infrastructure, service frequency, segregation practices, recycling initiatives, challenges, and regulatory compliance.

3.2.2.6 Data analysis and interpretation

After the collection of data, obtained data was computerized using Microsoft Word, and SPSS software, which will be used for data processing, analysis, tabulation, compilation, calculation, and interpretation, and ArcGIS Software was used for mapping.

The interpretation of data was performed using SPSS Software (SPSS 16) which helped us to produce figures, diagrams graphs, and percentages that were very important in the interpretation of results.

Quantitative analysis Data from reports, surveys, and potential waste management companies (e.g., waste collection volumes) was analyzed statistically to identify trends and patterns in waste generation and management practices. A household survey was conducted within Ngoma Sector,

stratified by socioeconomic status. The survey was gathering data on waste generation habits, participation in waste management programs, and satisfaction with waste collection services.

Qualitative analysis Information from interviews, news articles, and open-ended survey questions was analyzed thematically to understand perceptions, challenges, and potential solutions from the perspectives of various stakeholders Government Reports & Research Papers Content analysis to identify key policies, regulations, challenges, and best practices. Semi-structured interviews were conducted with waste collectors, sorting facility workers, and local waste management officials. Site visits were conducted at waste collection points and the Sovu landfill. These methods will provide insights into operational challenges, resident behavior, and infrastructure limitations.

By combining quantitative and qualitative data, the study gains a more nuanced understanding of waste management challenges in Ngoma sector. Qualitative data helps explain the "why" behind the quantitative data, providing richer insights. Combining data sources allows for the development of targeted solutions that address the root causes of waste management issues identified in Ngoma Sector.

3.3 Materials

To enhance the feasibility of this research, some materials were used:

Digital cameras were visualized to document solid waste disposal sites, including landfill sites, open dumping areas, and waste collection points.

CHAPTER FOUR: PRESENTATION OF RESULTS

This chapter presents the study's key findings on the challenges of solid waste management in Butare cell. It includes an analysis of resident demographics, household waste generation and disposal habits, and the city's overall waste management situation. Data was collected using surveys, observations, and interviews, and analyzed using statistical methods.

4.1. Demographic characteristics of respondents

4.1.1. Distribution of respondents by sex and age

The study analyzed data from both male and female participants to investigate potential gender disparities in the challenges related to solid waste disposal. The following table presents the demographic breakdown of respondents by age and gender.

Table 2: Respondents by age group and sex

Age range	Gender		Total
	Male	Female	
18-29	11	0	11
30-39	14	23	37
40 beyond	0	52	52
Total	25	75	100

Source: Author, 2024

The demographic analysis of respondents revealed that 75% were female and 25% were male. The majority of respondents were aged 40 and beyond (52%), followed by those aged 30-39 (37%), and 18-29 (11%). This distribution indicates a predominantly older and female population, which may influence waste generation patterns and disposal behaviors.

The study in Ngoma sector found a significantly higher representation of females (75%) compared to males (25%). The observed gender distribution may reflect the societal roles prevalent in many African communities, where women often take on primary responsibility for household management, including waste disposal. Similar gender dynamics have been documented in other African studies, underscoring women's pivotal role in domestic waste management. For example, a study in Accra, Ghana, revealed that women were more actively involved in waste sorting and disposal activities due to their household responsibilities (Oduro-Kwarteng, 2012). This

consistency highlights the need for gender-sensitive waste management interventions that acknowledge and support women's crucial role in this area. The predominance of female and older respondents in Butare cell suggests that waste generation and disposal patterns may be closely linked to household management practices. Older individuals and women, being more involved in daily household activities, may influence the types and amounts of waste generated, particularly organic and household waste.

Previous studies in African settings also highlight the connection between demographic factors and waste generation patterns. For example, research in South Africa found that older households tended to generate more organic waste due to traditional cooking practices, while younger households generated more plastic waste due to higher consumption of packaged goods (Godfrey & Oelofse, 2017). This comparison suggests that understanding the demographic characteristics of a population is crucial for developing targeted waste management strategies.

The demographic characteristics of the respondents suggest that waste disposal behaviors in Huye District may be influenced by long-standing practices associated with age and gender roles. Women and older individuals may adhere to traditional methods of waste disposal, which could affect the adoption of modern waste management practices.

In other African studies, similar demographic influences on waste disposal behaviors have been observed. For instance, research in Ethiopia found that older women were more likely to engage in traditional waste disposal methods, such as backyard burning, which may conflict with modern environmental regulations (Tassie Wegedie, 2018). This finding underscores the importance of considering demographic factors when implementing new waste management policies or technologies, ensuring they are accessible and acceptable to all community members.

The demographic analysis of respondents in Ngoma sector reflects broader trends observed in previous African studies, where gender and age significantly influence the waste generation and disposal behaviors. These findings highlight the need for waste management strategies tailored to the population's specific demographic characteristics, ensuring that interventions are effective and culturally appropriate. By acknowledging and addressing these demographic factors, waste management programs in Ngoma sector and similar contexts can achieve greater success in promoting sustainable waste disposal practices.

4.1.2. Distribution of respondents by marital status

Table 3: Respondents by marital status and level of education

Level of education	Marital Status				Total
	Single	Married	Widowed	Divorced	
No Education	1	0	0	0	1
Primary education	18	0	0	0	18
Secondary education	11	18	0	0	29
High education	0	25	0	0	25
TVT education	0	12	10	5	27
Total	30	55	10	5	100

Source: Author, 2024

The majority of the respondents in Ngoma sector were married (55%), followed by single (30%), widowed (10%), and divorced (5%). Marital status can play a role in household decision-making processes, including waste management. Married individuals, often part of larger households, may generate more waste and thus have a greater need for efficient waste disposal practices.

Similar patterns have been observed in other African studies. For example, a study in Nigeria found that married households tended to generate more waste compared to single or widowed individuals due to larger family sizes and the associated household activities (Babayemi & Dauda, 2010). This implies that waste management strategies should consider household size and structure when designing interventions, as different marital statuses may influence waste generation and management behaviors.

The study in Butare cell revealed that a significant portion of the population is relatively well-educated, with 81% having at least secondary education, including 27% with TVT education and 25% with higher education. Education levels are often correlated with awareness and adherence to environmental practices, suggesting that this population could be more receptive to educational campaigns and initiatives aimed at improving waste management practices.

In other African contexts, education has been identified as a key factor in determining the success of waste management programs. For example, research in South Africa found that higher levels of

education were associated with greater participation in recycling programs and other environmentally sustainable practices (Strydom, 2018). Additionally, a study in Ethiopia noted that individuals with higher education were more likely to engage in proper waste segregation and disposal (Bjerkli, 2013). The implications of these findings suggest that in Butare cell, leveraging the relatively high education levels could enhance the effectiveness of waste management programs, as educated individuals are more likely to understand and adopt new waste disposal practices.

The relatively high level of education among the respondents in Butare cell offers an opportunity to implement more sophisticated and knowledge-based waste management programs. Educated populations are generally more likely to engage in waste segregation, recycling, and other environmentally friendly practices. This suggests that targeted educational campaigns and training sessions could be highly effective in promoting better waste management practices in the area.

Previous studies in Africa reinforce the idea that education is a critical enabler for successful waste management. For instance, in Kenya, educational initiatives have been linked to increased recycling rates and better waste handling (Douti et al., 2017). Therefore, in Butare cell, the focus should be on designing educational programs that are tailored to different education levels, ensuring that all segments of the population can contribute to improved waste management.

The predominance of married individuals in the study suggests that waste management strategies in Butare cell should consider the unique needs of larger households. Married individuals, often managing households with multiple members, may require different waste disposal solutions compared to single or widowed individuals.

Similar implications have been observed in previous studies across Africa. In Ghana, for example, research found that married households were more likely to participate in community-based waste management programs due to the higher waste generation associated with family activities (Paul et al., 2019). This indicates that waste management policies in Butare cell could benefit from addressing the specific needs of married households, such as providing adequate waste collection services for larger families or offering incentives for bulk waste reduction.

The demographic profile of respondents in Butare cell, particularly in terms of marital status and educational attainment, aligns with findings from previous studies in Africa, highlighting the importance of these factors in shaping waste management behaviors. The relatively educated

population presents a significant opportunity to enhance waste management practices through targeted educational initiatives, while the prevalence of married households suggests the need for tailored waste disposal solutions. By understanding and addressing these demographic factors, waste management strategies in Butare cell can be more effectively designed and implemented, leading to better environmental outcomes.

4.1.3. Distribution of respondents by family size

Considering family size alongside other demographic and behavioral factors is essential for designing effective waste management policies and infrastructure in Ngoma sector. The table below presents the average family size in Butare cell.

Table 4: Respondents by family size

Family size	Percent
1 Person	5.0
2-3 persons	36.0
4-5 Persons	48.0
6-7 Persons	8.0
Above 7 Persons	3.0
Total	100.0

Source: Author, 2024

Referring to the information from the table above shows that 48% of respondents consist of 4 to 5 persons, 36% of respondents consist of 2 to 3 persons, 8% of respondents consist of 6 to 7 persons, 5% of respondents consist of only 1 person while the small group of respondents has above 7 persons as a family member accounting 3% of respondents. This distribution provides insights into the average family size in the city, which is crucial for planning waste management strategies.

In a study conducted in Accra, Ghana, it was found that larger households tend to generate more waste, which has implications for waste collection and disposal services (I. D. Amoah et al., 2018). Similarly, research in Lagos, Nigeria, by (Yakubu, 2017) emphasized that household size directly correlates with the volume of waste generated, necessitating tailored waste management strategies. The data showing that 48% of households have 4 to 5 members, and 36% have 2 to 3 members, suggests that the majority of households fall within a moderate size range. This is consistent with findings from other African cities where average family sizes are similar. Waste management

strategies in such contexts must account for the volume of waste generated by these household sizes, ensuring that collection and disposal services are adequately scaled to meet demand.

In Dar es Salaam, Tanzania, (Mkude & Saria, 2015) noted that smaller households, including those with single occupants, generate less waste but may face challenges such as the inefficiency of waste collection services tailored for larger households. With 5% of respondents living alone, waste management strategies should consider the specific needs of smaller households. For instance, collection schedules and bin sizes might need to be adjusted to avoid underutilization of services, which could be more common in areas with a higher percentage of single-person households.

A study in Nairobi, Kenya, found that larger households (6 or more members) contributed disproportionately to the total volume of waste generated, leading to challenges in waste management, especially in informal settlements where services are limited (UN-HABITAT, 2010). With 8% of households having 6 to 7 members and 3% having more than 7 members, the city must consider the implications of higher waste generation in these households. Larger households are likely to produce more waste, which requires efficient and frequent waste collection services to prevent waste accumulation and potential health hazards.

The distribution of household sizes indicates the need for waste management services that are responsive to different household sizes. For example, areas with a high concentration of 4 to 5 member households may require larger bins and more frequent collections to handle the volume of waste generated. Understanding the distribution of household sizes can help in allocating resources effectively. For instance, areas with a higher percentage of larger households might need additional waste management resources, including more collection points and larger bins.

The data on household sizes can inform the planning of waste management infrastructure, such as the placement of waste collection points, the sizing of waste bins, and the design of collection routes. This ensures that waste management services are efficient and cater to the needs of different household sizes also Policymakers can use the insights from household size distribution to develop policies that support waste reduction initiatives. For example, incentives for recycling and composting could be designed to address the specific needs of households of varying sizes.

4.1.4. Distribution of respondents by family income

Table 5: Monthly income of respondents

Family income	Percent
Below 35,000 RWF	10.0
35,000 - 50,000 RWF	13.0
50,000 - 100,000 RWF	49.0
100,000 - 200,000 RWF	25.0
Above 200,000 RWF	3.0
Total	100.0

Source: Author, 2024

The data indicating that 49% of respondents have a monthly income between 50,000 and 100,000 Rwf, with 10% earning below 35,000 Rwf, highlights a significant economic challenge for many households in Butare Cell when it comes to affording waste management services. This income distribution suggests that a substantial portion of the population may struggle to pay for regular waste collection or recycling services, which could lead to inadequate waste disposal practices and environmental degradation.

Similar challenges have been observed in other African cities where low-income households face difficulties in accessing waste management services. For example, in Nairobi, Kenya, a study found that low-income areas often have limited waste collection services, leading to higher instances of illegal dumping and open burning of waste, which exacerbates environmental and health issues (Muiruri et al., 2020). In these cases, the affordability of waste management services is a critical barrier to effective urban environmental management.

To address these economic barriers, subsidies or alternative financing models, such as pay-as-you-throw schemes or community-based waste management initiatives, have been suggested as viable solutions. For instance, in Lagos, Nigeria, the introduction of a public-private partnership in waste management has allowed for more inclusive service provision, though challenges remain in ensuring that all income groups are served equitably (Olukanni & Nwafor, 2019).

The income distribution in Butare cell also correlates with waste generation patterns, as observed in other studies. Higher-income households tend to generate more waste, particularly non-biodegradable waste, due to higher consumption levels of packaged goods. In contrast, lower-

income households often generate less waste but are more likely to struggle with accessing formal waste management services. This pattern is consistent with findings in other African cities, such as Addis Ababa, Ethiopia, where income disparities significantly impact waste management outcomes (Zemena, 2016).

The economic disparities in Ngoma sector, targeted interventions are necessary to ensure that all households, regardless of income, have access to reliable waste management services. This could include government subsidies for low-income households, community-based waste management programs, or sliding scale fees based on income. These measures would help mitigate the risk of environmental harm due to inadequate waste disposal practices among economically disadvantaged populations.

4.1.5. Distribution of respondents by length of residence in Butare cell

This distribution provides insights into the duration of residency among residents, which can impact their familiarity with local waste management practices and their integration into community waste management initiatives.

Table 6: Duration of residence of respondents in Butare cell

Number of years	Percent
Below 1 year	7.0
1-5 years	36.0
Above 5 years	57.0
Total	100.0

Source: Author, 2024

Table 6, the data revealing that 57% of respondents have been residing in Butare cell for more than 5 years, 36% for 1 to 5 years, and 7% for less than 1 year provides insight into the stability and demographic trends of the city's population. This stability is crucial in understanding waste generation patterns and the potential for long-term community engagement in waste management practices.

In many African cities, long-term residency often correlates with better integration into community practices, including waste management. A study in Accra, Ghana, found that residents who had lived in the city for more than 5 years were more likely to participate in organized waste management practices, compared to newer residents who were less familiar with local systems and

regulations (S. T. Amoah & Kosoe, 2014). Similarly, long-term residents in Dar es Salaam, Tanzania, were found to have a better understanding of waste disposal practices and were more likely to adhere to waste collection schedules, compared to newer residents (Mhache, 2012).

The fact that a majority (57%) of the population in Butare cell has been residing there for more than 5 years suggests potential for stronger community-based waste management initiatives. Long-term residents are more likely to have established routines and a vested interest in maintaining the cleanliness and environmental health of their surroundings. This stability could be leveraged to promote waste reduction strategies, recycling programs, and consistent participation in waste management efforts.

However, 7% of respondents who have been residing in Butare cell for less than 1 year may face challenges in adapting to local waste management practices. Studies in African cities like Kigali, Rwanda, have shown that new residents often struggle with understanding and complying with local waste disposal regulations, which can lead to improper waste management and increased environmental degradation (Victoire et al., 2020). New residents might lack awareness of waste collection schedules or the availability of recycling facilities, leading to issues such as illegal dumping or non-segregated waste disposal. To address the challenges faced by newer residents, targeted education and awareness campaigns could be implemented to ensure they are quickly integrated into the city's waste management practices. This could include providing information on waste collection points, recycling opportunities, and penalties for non-compliance. Moreover, engaging long-term residents in mentoring or community leadership roles could help bridge the gap between new and established residents, fostering a more cohesive approach to waste management.

4.2. Household waste generation and disposal

The composition of household waste highlights that food scraps are the predominant type of waste generated, paper products and plastic packaging also constitute significant portions of household waste, and glass and metal containers, along with hazardous materials, represent smaller proportions of waste generated.

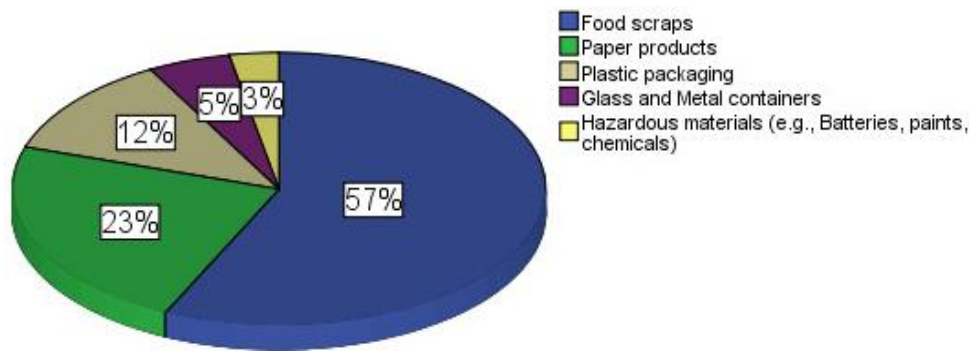


Figure 3: Types of solid waste

Source: Author, 2024

The data shows that among the 100 respondents surveyed, 57% of households generate food scraps, 23% generate paper products, 12% generate plastic packaging, 5% generate glass and metal containers, and only 3% generate hazardous materials such as batteries, paints, and chemicals. This distribution highlights that organic waste (food scraps) is the dominant waste generated by households, followed by paper, plastic, and then glass/metal containers. Hazardous waste constitutes a small portion of household waste.

The fact that 57% of households in the study generate food scraps aligns with a broader trend observed in many African countries where organic waste tends to dominate the household waste stream. This is consistent with findings from studies conducted in other parts of Africa. For example, a study in Accra, Ghana, found that organic waste accounted for over 60% of the total household waste generated (Fobil et al., 2008). Similarly, in Nairobi, Kenya, organic waste comprised about 65% of the total household waste (Kathambi & Ogutu, 2022). This dominance of organic waste suggests that composting and other organic waste management strategies should be prioritized in Ngoma sector, as they can significantly reduce the overall waste burden.

The study found that only 3% of households generate hazardous materials. This is a relatively small proportion, which is similar to the findings in other African contexts. In a study conducted in Addis Ababa, Ethiopia, hazardous waste constituted about 2-4% of the total household waste (Bjerkli, 2013). The low proportion of hazardous waste suggests that while it may not be a significant portion of household waste, its proper disposal is crucial to prevent environmental

contamination. This finding indicates the need for specialized collection and disposal systems for hazardous waste, even if its volume is low.

The survey indicated that 23% of households generate paper products, 12% generate plastic packaging, and 5% generate glass and metal containers. These materials are typically considered recyclable. The proportions are somewhat lower than those found in more industrialized regions of Africa. For instance, in Johannesburg, South Africa, recyclable materials such as paper, plastics, and metals were found to make up approximately 30-40% of household waste (Strydom, 2018). The lower percentages in Butare cell could imply a lower consumption of packaged goods or a lack of robust recycling systems and market demand for recyclables.

Focus on Organic waste management forms the largest portion of household waste in Ngoma sector, similar to other parts of Africa, the implementation of composting programs could be highly effective. The success of such initiatives in other African cities, such as the composting program in Ouagadougou, Burkina Faso (Sanfo et al., 2022), suggests that Ngoma sector could similarly benefit from reducing the volume of waste sent to landfills while also producing valuable compost for agricultural use.

Although hazardous waste constitutes a small fraction of household waste, its proper management is essential to prevent environmental and public health risks. The findings align with previous studies emphasize the need for specialized hazardous waste collection systems, even if the volume is small. For instance, in Cairo, Egypt, the introduction of household hazardous waste collection points significantly reduced the improper disposal of batteries and chemicals (El-Sayed, 2022). Ngoma could implement similar initiatives to ensure hazardous materials are safely managed.

The relatively low generation of recyclable materials in Ngoma sector compared to other African cities suggests a potential area for improvement. Strategies could include increasing public awareness about recycling, improving the infrastructure for collecting recyclable materials, and developing markets for recycled products. Learning from successful recycling programs in cities like Dar es Salaam, Tanzania, where community-based recycling initiatives have gained traction (Mhache, 2012), could inform the development of effective recycling strategies in Ngoma sector. The waste composition data from Ngoma sector, which shows a high proportion of organic waste and a lower generation of recyclables and hazardous materials, is consistent with findings from

other African cities. These similarities suggest that waste management strategies that have been successful in other parts of Africa, such as composting and the development of recycling infrastructure, could be adapted and applied in Ngoma sector. Additionally, the specialized handling of hazardous waste, even in small quantities, remains a critical area for ensuring environmental compliance and public health safety.

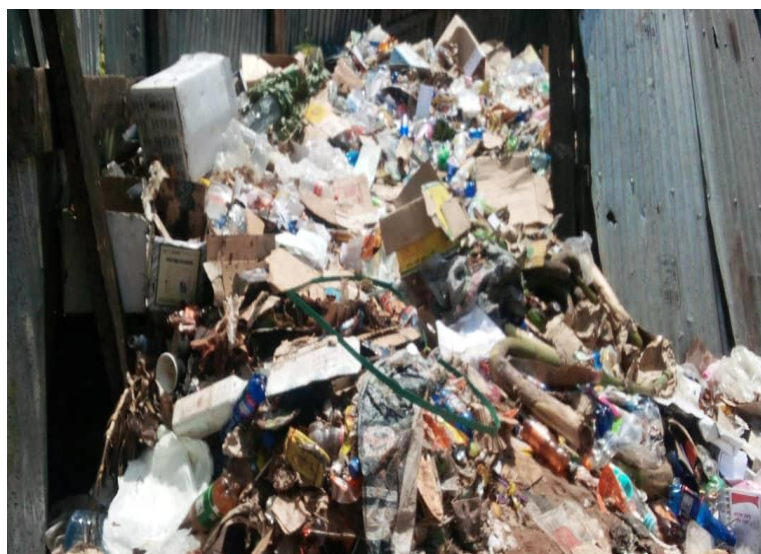


Figure 4: Types of solid waste of Butare cell

Source: Author, 2024

Table 7: Volume of waste produced per week

Solid waste produced	Percent
Less than 5 Kg	25.0
5-10 kg	55.0
10-20 kg	17.0
More than 20 kg	3.0
Total	100.0

Source: Author, 2024

The data indicates that the majority of households in Butare cell generate 5-10 kg of waste per week, with food scraps (57%) being the predominant type of waste, followed by paper products (23%) and plastic packaging (12%), emphasizes the need for focused waste management

strategies, particularly in reducing and recycling organic and recyclable materials. In comparison to other African cities, the waste generation pattern in Butare cell aligns with broader regional trends where organic waste constitutes the majority of household waste. For example, a study in Nairobi, Kenya, found that organic waste accounted for approximately 60% of total household waste, followed by plastics (20%) and paper (10%) (Muiruri et al., 2020). Similarly, in Dar es Salaam, Tanzania, organic waste was found to make up 70% of the total municipal solid waste, highlighting the dominance of biodegradable materials in the waste stream (Mhache, 2012).

The findings from Butare cell suggest that targeted interventions aimed at managing organic waste could significantly improve overall waste management efficiency. For instance, the high proportion of food scraps provides an opportunity for composting initiatives, which could reduce the volume of waste sent to landfills and generate compost for agricultural use. This is similar to practices in Addis Ababa, Ethiopia, where organic waste is composted on a large scale to produce fertilizer, contributing to urban agriculture and reducing the strain on landfill sites (Alemu et al., 2024). The presence of paper products (23%) and plastic packaging (12%) in the waste stream also highlights the potential for recycling programs. Studies in other African cities, such as Lagos, Nigeria, have shown that recycling initiatives focused on paper and plastics can be effective in reducing waste volumes and generating economic benefits (Taiwo, 2009). For example, community-based recycling programs in Lagos have not only helped in waste reduction but also created job opportunities, particularly for women and youth. However, the successful implementation of waste reduction and recycling programs in Butare cell may face challenges similar to those observed in other African cities, such as limited public awareness, inadequate infrastructure, and financial constraints. A study in Kampala, Uganda, highlighted that despite the potential for recycling, the lack of proper waste sorting at the household level and limited access to recycling facilities have hindered the effectiveness of recycling initiatives (Christensen et al., 2014). To address these challenges, Butare cell could benefit from public education campaigns aimed at promoting waste segregation at the source, as well as investments in recycling infrastructure. Additionally, the city could explore partnerships with private sector companies to establish sustainable waste management and recycling programs, similar to successful models in other African cities.

Table 8: Current solid waste disposal methods

Solid waste disposal methods	Percent
Door to door collection by waste management service provider	50.0
Community collection point	3.0
Informal dumping	37.0
Burning waste	10.0
Total	100.0

Source: Author, 2024

The data on household waste disposal methods in Butare Cell shows that 50% of households use door-to-door collection services, 37% resort to informal dumping, and 10% opt for burning waste.

In a study conducted in Addis Ababa, Ethiopia, researchers found that organized waste collection services, especially door-to-door collection, significantly improved urban cleanliness and reduced informal dumping (Ezeudu et al., 2022). A similar trend was observed in Nairobi, Kenya, where expanded coverage of door-to-door services decreased reliance on informal waste disposal methods (Iddi et al., 2021).

The use of door-to-door collection services by 50% of households in Butare cell reflects a growing trend in many African urban areas where formal waste collection is becoming more prevalent. The significant uptake of these services indicates successful implementation and trust in the system, which is essential for improving overall waste management and reducing environmental health risks. Expanding these services could further reduce informal dumping and burning, aligning with sustainable waste management goals. Informal dumping is a common issue in many African cities due to inadequate waste management infrastructure. In Lagos, Nigeria, a study highlighted that over 60% of waste was disposed of informally, mainly due to the lack of accessible formal waste collection services (Afon & Abegunde, 2015). Similarly, in Dar es Salaam, Tanzania, informal dumping was prevalent in areas underserved by municipal waste services (Mbuligwe, 2002).

With 37% of households in Butare cell resorting to informal dumping, this mirrors the challenges faced in other parts of Africa where formal waste management services are either insufficient or inaccessible. This practice poses significant environmental and health risks, such as water

pollution and vector-borne diseases. Addressing the barriers to formal waste collection, such as cost and convenience, could help reduce the reliance on informal dumping. The data suggests a need for targeted interventions to expand coverage and educate residents about the risks associated with informal disposal.

The data indicating that 10% of households in Butare cell burn their waste aligns with findings from other African studies where waste burning is a default disposal method due to a lack of alternatives. This practice contributes to air pollution and poses significant health risks, particularly respiratory issues. To mitigate these impacts, it is crucial to improve access to waste collection services and promote alternative disposal methods, such as composting for organic waste.

The provision of regular and reliable door-to-door collection services could significantly reduce the need for households to resort to burning or burying waste, thereby mitigating the associated environmental and health risks. Public education is also critical in addressing the issue of improper waste disposal. In many African cities, such as Accra, Ghana, awareness campaigns have proven effective in reducing the prevalence of burning and other harmful waste disposal practices by educating residents about the benefits of proper waste management (Twumasi, 2017). Butare cell could benefit from similar initiatives, focusing on the dangers of burning waste and promoting environmentally friendly alternatives.



Figure5: Informal dumping site (Source: Author, 2024)



Figure 6: Informal dumping site

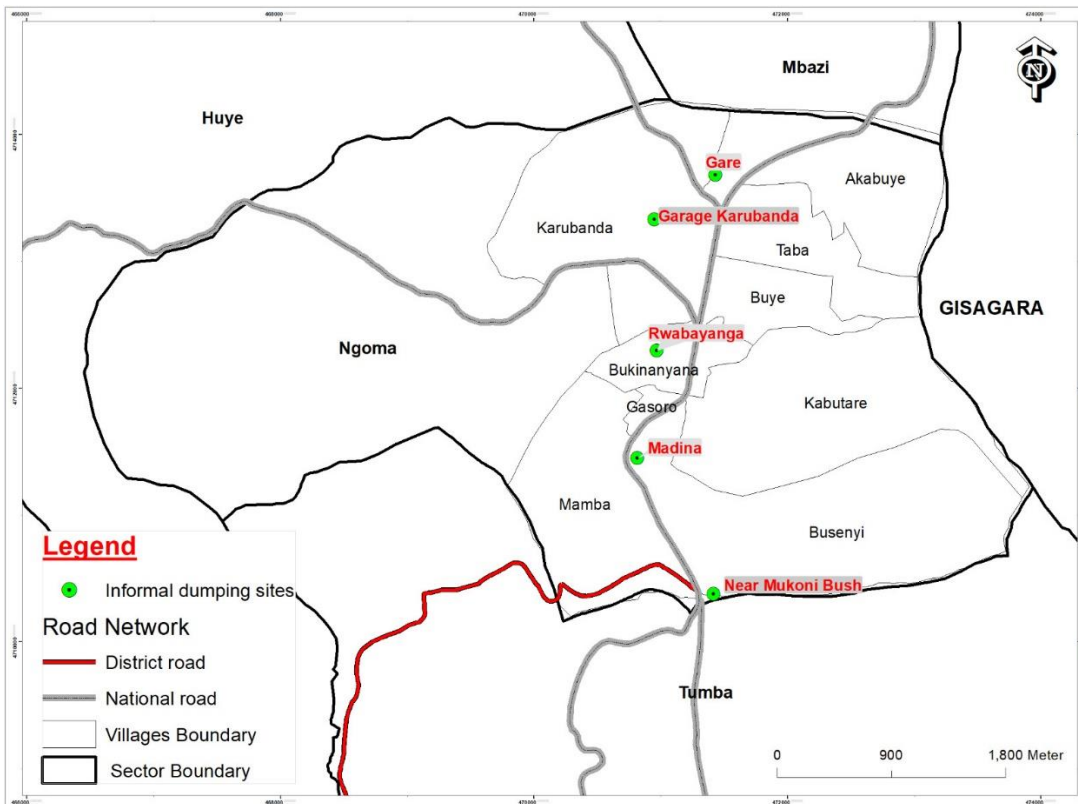


Figure 7: Map of informal dumping site (Source: Author, 2024)

4.2.1. The challenges facing solid waste management

Butare cell, like many urban centers, struggles with several waste management issues that negatively affect the environment, public health, and overall quality of life. Table 9 provides a detailed overview of these challenges.

Table 9: Challenges facing solid waste management in Butare cell

Challenges facing solid waste management	Percent
Insufficient collection frequency	32.0
High cost of collection services	15.0
Lack of awareness of recycling and composting options	10.0
Difficulty in separating different types of waste	33.0
Long distance to disposal facilities	10.0
Total	100.0

Source: Author, 2024

Key challenges in Butare Cell's solid waste management include infrequent collection, difficulties in waste sorting, and high collection costs, as reported by 32%, 33%, and 15% of respondents, respectively. To address these issues, a comprehensive approach is needed, encompassing improvements to waste collection infrastructure, public education on waste separation, and increased financial resources for waste management services.

Infrequent collection is a significant issue in Butare cell, as reported by 32% of respondents. This challenge is common across many African cities. For example, in Lagos, Nigeria, studies have shown that irregular waste collection is a major problem due to inadequate resources and poor urban planning (Momodu et al., 2011). Similarly, in Dar es Salaam, Tanzania, less than half of the solid waste generated is collected regularly, leading to environmental degradation and health risks (Yhdego & Consultancy, 2022). The implications for Butare cell are clear there is a need to bolster the frequency and reliability of waste collection services to avoid similar environmental and public health consequences.

Waste sorting difficulties were reported by 33% of respondents in Butare cell. This issue is also prevalent in other African contexts. For instance, in Nairobi, Kenya, there is minimal separation of waste at the source, primarily due to a lack of public awareness and inadequate facilities for

sorting (Abdel-Shafy & Mansour, 2018). In Kigali, despite efforts to promote waste sorting, the practice is still not widely adopted, with a significant portion of recyclable materials ending up in landfills (Rajashekar et al., 2019). The implication for Butare cell is that public education and awareness campaigns, coupled with the provision of adequate sorting facilities, are crucial to improving waste sorting practices.

High collection costs were identified by 15% of respondents as a barrier to effective waste management in Butare cell. High costs are a common obstacle in many African cities, where waste management services often struggle with limited budgets. In Accra, Ghana, the cost of waste collection is a major challenge, leading to low service coverage and reliance on informal waste pickers (Fobil et al., 2008). In Johannesburg, South Africa, while there are more resources, the cost of managing waste, especially in low-income areas, remains a significant burden (Strydom, 2018). For Butare cell, addressing high collection costs could involve exploring cost-sharing models, subsidies, or enhancing the efficiency of waste management operations to reduce expenses.

The challenges of infrequent waste collection and high costs highlight the need for significant improvements in waste management infrastructure in Butare cell. Drawing lessons from cities like Kigali and Johannesburg, where investment in infrastructure has led to more efficient waste collection systems, Butare cell can benefit from a similar approach, ensuring that waste is collected regularly and managed cost-effectively.

Distance to disposal facilities has been identified as a significant factor affecting waste management practices across many African countries. In a study conducted in Kampala, Uganda, it was found that households located far from disposal sites were more likely to resort to informal dumping or burning due to the inconvenience and costs associated with long-distance travel to designated landfills (Mugagga Frank, 2006). Similarly, research in Accra, Ghana, revealed that the proximity of households to disposal sites was directly correlated with the likelihood of using formal waste management services, with greater distances leading to higher rates of illegal dumping (Ruo Cheng & Badolo, 2020).

The issue of long distances to waste disposal facilities, as indicated by the 10% of households in Butare cell facing challenges due to the landfill's location, aligns with findings from other parts of Africa. This logistical barrier contributes to the persistence of informal dumping and burning practices, as households may lack the resources or willingness to transport waste over long

distances. To address this, there is a need to decentralize waste management facilities and establish more localized disposal or collection points, making it easier for residents to access and utilize formal services. Implementing mobile waste collection services can be an effective solution for areas where residents face long distances to disposal sites. These services can offer a more flexible and convenient option for waste disposal, particularly in densely populated or hard-to-reach areas. The difficulty in waste sorting underscores the importance of public education and engagement. Like in Nairobi and Kigali, where public awareness campaigns are essential to encouraging waste separation at the source, Butare cell must invest in education initiatives that inform residents about the benefits and practices of waste sorting. This could help reduce the burden on landfills and improve recycling rates. The high collection costs in Butare cell, similar to the financial challenges faced in Accra, suggest that increasing financial resources for waste management is critical. This could involve enhancing budget allocations, seeking external funding, or introducing innovative financing mechanisms like public-private partnerships to ensure sustainable waste management practices. The challenges identified in Butare cell such as infrequent waste collection, difficulties in waste sorting, and high collection costs mirror issues faced in many other African cities. By addressing these challenges through improved infrastructure, public education, and financial resource allocation, Butare cell can enhance its solid waste management practices. The experiences of other African cities provide valuable lessons and models that Butare cell can adapt to its context, ultimately leading to more effective and sustainable waste management.

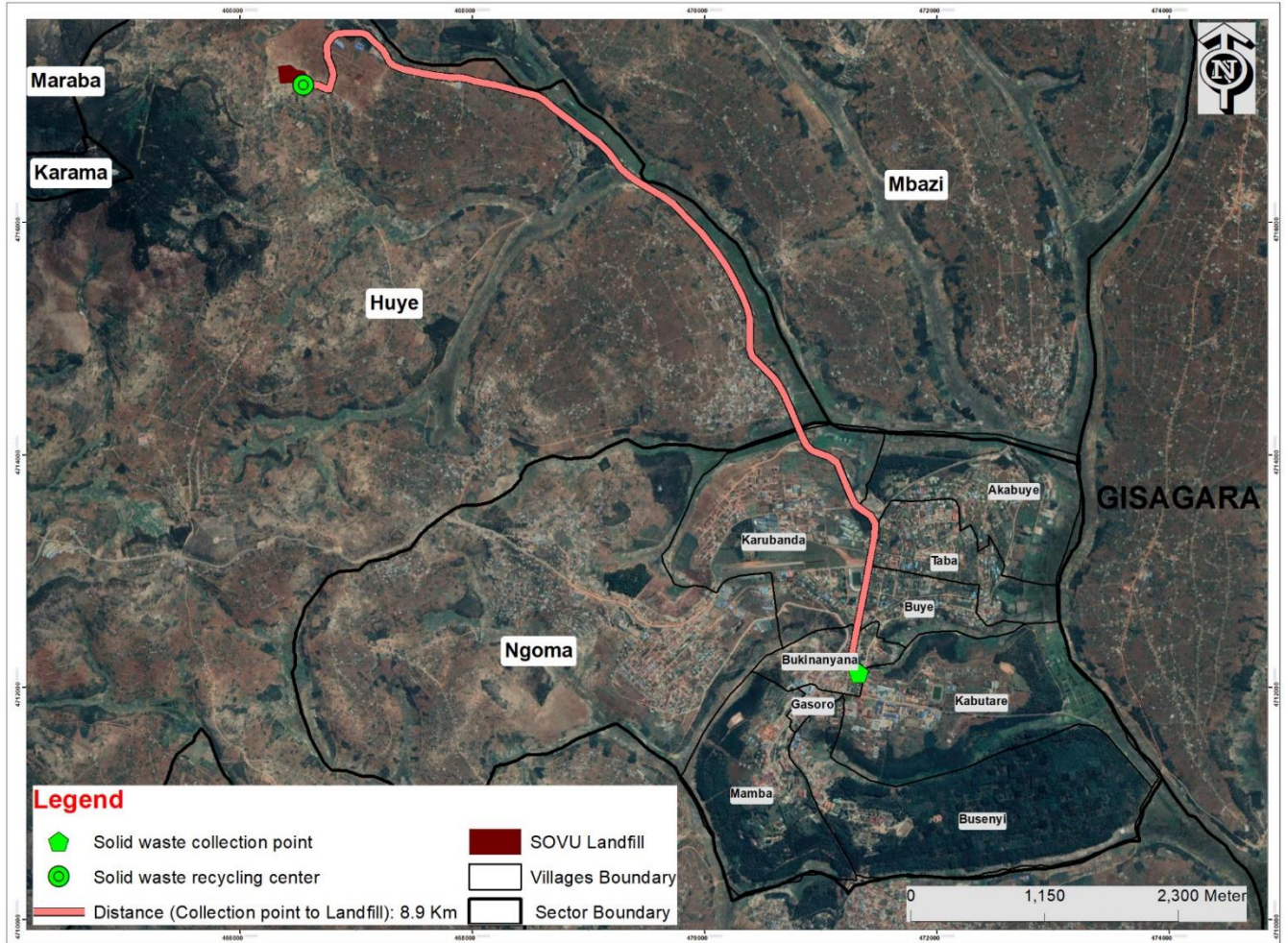


Figure 8: Distribution of solid waste disposal facilities

Source: Author, 2024



Figure 9: Solid waste recycling center (Source: Author, 2024)

4.2.2. The current state of solid waste management

The current state of solid waste management in Butare cell is influenced by several key reasons, as provided in the table below.

Table 10: Reasons for the current state of solid waste management

What do you think are the main reasons for the current state of solid waste management in Butare cell?	Percent
Inadequate infrastructure	18.0
Lack of funding	12.0
Lack of public awareness	27.0
Ineffective regulations	43.0
Total	100.0

Source: Author, 2024

This proven by the information from respondents provided in table 10, where 43% of respondents indicated ineffective regulations as a significant issue. This implies that Weak enforcement of existing waste management laws and regulations allows for illegal dumping, burning of waste, and non-compliance with waste segregation requirements also ineffective regulations fail to provide incentives or penalties necessary to ensure compliance and responsible waste management practices, 27% of respondents mentioned lack of public awareness as a major reason where many residents may not fully understand the importance of proper waste disposal practices, 18% of respondents cited inadequate infrastructure as reason for the current state of solid waste management where by insufficient infrastructures such as limited waste collection system, inadequate disposal facilities and lack of recycling centers hinder effective waste management practices and 12% of respondents identified lack of funding as a significant challenge where by limited financial resources restrict investment in upgrading existing waste management infrastructures.

The challenge of ineffective regulations is not unique to Butare cell; it is a common issue across many African cities. Weak enforcement of existing waste management laws and regulations has been documented as a major barrier to effective waste management. For instance, in Lagos, Nigeria, poor regulatory enforcement has led to widespread illegal dumping and open burning of

waste, which are significant contributors to environmental degradation and public health issues (Nzeadibe, 2009). Similar patterns have been observed in Nairobi, Kenya, where the lack of stringent enforcement of waste management laws has resulted in non-compliance with waste segregation and disposal practices (Ali et al., 2010). The situation in Butare cell underscores the need for stronger regulatory frameworks and enforcement mechanisms to ensure compliance and promote responsible waste management.

The lack of public awareness about proper waste disposal practices is another critical issue that parallels challenges observed in other parts of Africa. Public education on waste management is often inadequate, leading to poor waste disposal behaviors. In Dar es Salaam, Tanzania, a lack of awareness and education has been identified as a key factor contributing to improper waste disposal practices, with many residents unaware of the environmental and health impacts of their actions (Mhache, 2012). The findings from Butare cell suggest that similar educational gaps exist, which need to be addressed through targeted awareness campaigns and community engagement initiatives to improve waste management outcomes.

Inadequate infrastructure is a widespread challenge in solid waste management across many African cities. The findings from Butare cell, where respondents cited insufficient waste collection systems, inadequate disposal facilities, and a lack of recycling centers, reflect the infrastructural deficits that hinder effective waste management. A study conducted in Addis Ababa, Ethiopia, similarly identified inadequate infrastructure as a significant barrier to efficient waste management, leading to the proliferation of informal dumping sites and poor waste collection services (Assefa, Taye & Simane, 2024). These infrastructural challenges highlight the need for substantial investments in waste management systems to enhance their capacity and efficiency in handling solid waste. The issue of limited financial resources restricting investment in waste management infrastructure is a common theme in many African cities. In Kampala, Uganda, for example, the lack of adequate funding has been a major obstacle to improving waste management services, resulting in insufficient waste collection coverage and inadequate facilities for waste disposal (Iyanda & A., 2014). The situation in Butare cell is indicative of the broader financial constraints faced by local governments in Africa, which limit their ability to invest in modern waste management technologies and infrastructure. Addressing this challenge will require innovative financing models and increased budget allocations to support sustainable waste management practices.

The challenges identified in Butare cell mirror those found in other African cities, emphasizing the need for a multi-faceted approach to improving waste management. Strengthening regulatory frameworks, enhancing public awareness, upgrading infrastructure, and securing adequate funding are essential steps to overcoming these barriers. Policymakers and stakeholders in Butare Cell should consider these lessons from other African contexts to develop more effective waste management strategies that are tailored to the local realities and needs.

4.2.3. Waste reduction methods

Through the emphasis on the waste reduction methods provided in figure 10, show overall waste management strategies, promote environmental sustainability, and foster a more responsible approach to consumption and waste generation among its residents.

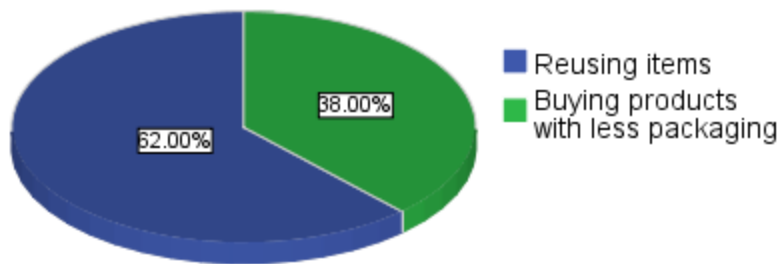


Figure 10: Figure: Waste reduction methods

Source: Author, 2024

Based on the information from respondents as shown in the table above 62% of households practice reusing items as a method of waste reduction while 38% of households choose to buy products with less packaging to reduce waste.

The practice of reusing items as a waste reduction strategy is prevalent in many African cities, particularly in contexts where formal recycling systems are underdeveloped or inaccessible. For example, in Nairobi, Kenya, a study by (M. Aurah, 2013) found that a significant proportion of households engage in reusing items such as containers, bags, and bottles to minimize waste. This practice is driven by both economic considerations and environmental awareness. Similarly, in Lagos, Nigeria, informal waste management practices, including reusing items, are common as a means of coping with inadequate waste collection services (Ogwueleka, 2009). The high percentage of households practicing reusing in Butare cell aligns with these trends and underscores

the importance of promoting and supporting such sustainable behaviors as part of broader waste management strategies.

The choice to purchase products with less packaging is another effective waste reduction strategy that is gaining traction in various parts of Africa. However, this practice is less widespread compared to reusing, possibly due to limited consumer choices and the availability of such products in local markets. In Johannesburg, South Africa highlighted that while there is increasing consumer awareness about the environmental impact of packaging, the market for products with minimal packaging is still emerging (de Vries et al., 2017). This situation is likely similar in Butare cell, where 38% of respondents are actively choosing products with less packaging. The findings suggest that with greater market availability and consumer education, this practice could become more prevalent, contributing significantly to waste reduction efforts.

The practices of reusing items and choosing products with less packaging have significant implications for waste management policies in Butare cell and other African contexts. Policymakers can leverage these behaviors by promoting public awareness campaigns that highlight the environmental and economic benefits of these practices. Additionally, encouraging manufacturers and retailers to reduce packaging and offer reusable products can further support these waste reduction strategies. The findings also suggest that there is a need for more targeted interventions that facilitate and incentivize these behaviors, such as providing resources for reusing items and supporting local markets that prioritize environmentally friendly packaging.



Figure 11: Organic fertilizer and plastic pavers transformed from waste

Source: Author, 2024

4.3. Source of information for awareness of waste management

The source of information provided in table 11 enhance public awareness, encourages behavior change towards sustainable waste management practices and foster a more environmentally friendly with the community.

Table 11: Sources of information for learning about waste management

Source of information	Percent
Television	10.0
Radio	40.0
Community meetings	45.0
Social media	5.0
Total	100.0

Source: Author, 2024

In Dar es Salaam, Tanzania, community meetings have been shown to be effective in engaging residents in discussions about waste management and environmental issues (Govender et al., 2023). Similarly, in Nairobi, Kenya, (UN-HABITAT, 2010) found that community meetings were crucial for increasing awareness and participation in waste management practices. The 45% of respondents attending community meetings reflects a significant level of engagement, consistent with findings from other African cities. Community meetings provide a valuable platform for interactive discussions and can enhance local understanding and participation in waste management. This suggests that fostering more such meetings could further improve community involvement and waste management outcomes.

In many African countries, radio is a widely used medium for disseminating information due to its broad reach and accessibility. In Lagos, Nigeria radio broadcasts were an effective tool for public awareness campaigns on waste management (Idamah, 2015). Similarly, in Accra, Ghana, radio was identified as a key source of information on environmental issues (Idamah, 2015). The 40% of respondents using radio for waste management information aligns with previous research, highlighting radio's role as a crucial communication tool. Given its wide reach and accessibility, leveraging radio broadcasts for waste management education can effectively reach a large audience and promote better waste management practices. While television is also a significant medium, its impact on waste management information dissemination is less pronounced compared to radio. Studies, such as those by Department of Environmental Affairs (2013) in Johannesburg, indicate that television is less commonly used for environmental education compared to other media (Wagenet et al., 2015). The 10% reliance on television for waste management information is lower than radio but still relevant. Television can complement other media by providing visual content that may enhance understanding. Increasing the use of television for waste management messages could further support education efforts, especially if combined with other media.

The 5% of respondents using social media for waste management information reflects its emerging but still limited role. As social media platforms continue to grow, they offer an opportunity for more targeted and interactive communication. Increasing social media outreach could engage younger audiences and complement traditional media efforts. The strong attendance at community meetings suggests that these events are effective for engaging residents. Expanding the frequency and reach of such meetings could enhance community involvement and foster more effective waste management practices. With 40% of respondents using radio for information, it remains a key

medium for disseminating waste management messages. Utilizing radio broadcasts to spread awareness and provide practical waste management tips can be highly effective.

While television and social media have lower usage rates for waste management information, they offer potential for broader outreach. Increasing content on these platforms could enhance awareness, particularly among demographics that use these media. A multi-faceted communication approach that includes community meetings, radio, television, and social media can address different audience needs and preferences. Combining these methods can maximize the impact of waste management education and engagement efforts.

4.4. Suggestion for improvement

4.4.1. Government actions to improve waste management

Based on the survey responses regarding specific actions that residents believe the government should take to improve waste management are highlighted in the table 12 below.

Table 12: Government actions to improve waste management

What specific actions do you think the government should take to improve waste management in Butare cell?	Percent
Expanding recycling options	15.0
Improving waste collection services	65.0
Implementing public education campaigns to promote waste reduction and proper disposal	20.0
Total	100.0

Source: Author, 2024

Referring to the information from the table above show that the survey responses indicate that 65% of residents believe improving waste collection services is a priority. The government should invest in more collection vehicles and expand collection points to ensure consistent and reliable waste collection. Additionally, 20% of respondents advocate public education campaigns to promote waste reduction and proper disposal practices. Implementing these actions can significantly enhance waste management in Butare cell.

In Lagos, Nigeria (Ichipi & Senekane, 2023) found that residents highly prioritized improvements in waste collection and management services. Similarly, a study in Accra, Ghana, indicated that residents felt that better waste collection infrastructure was essential for effective waste management (Duna, 2015). The 65% of residents prioritizing waste collection services reflects a common sentiment across various African cities. Effective waste collection is often seen as a fundamental step in improving overall waste management. Investing in collecting vehicles and expanding collection points are critical actions to address this priority, as they directly impact the efficiency and reliability of waste collection services.

Research in Dar es Salaam, Tanzania, showed that expanding waste collection infrastructure, including increasing the number of collection vehicles and establishing additional collection points, was vital for improving waste management outcomes (Mkude & Saria, 2015).

In Johannesburg, South Africa, the Department of Environmental Affairs also highlighted the importance of investing in infrastructure to enhance waste management services. The recommendation to invest in more vehicle collection and expand collection points aligns with the best practices identified in other studies. Improving infrastructure can lead to more efficient waste collection, reduced incidences of illegal dumping, and overall better waste management. This approach is crucial for addressing the significant waste management challenges faced by many African cities (Nyika et al., 2019).

A study in Nairobi, Kenya, found that public education campaigns were essential for promoting waste reduction and proper disposal practices (UN-HABITAT, 2010). Similarly, in Kinshasa, Democratic Republic of Congo (Kang et al., 2023) emphasized that community education was crucial for effective waste management and reducing environmental impact. The 20% of respondents advocating public education campaigns reflect a recognition of the role that awareness and education play in waste management. Effective public education can lead to more responsible waste disposal behaviors and support efforts to reduce waste generation. Integrating education with improved infrastructure creates a comprehensive approach to waste management.

The findings suggest that policymakers should prioritize investments in waste collection infrastructure, including increasing the number of collected vehicles and expanding collection points. This aligns with successful strategies observed in other African cities.

Combining infrastructure improvements with public education campaigns can enhance the effectiveness of waste management efforts. Public education can complement the increased capacity provided by better infrastructure, leading to more sustainable waste management practices. Engaging residents in discussions about waste management priorities and solutions can lead to more effective and supported waste management strategies. Public input, as seen in the survey, is valuable for tailoring interventions to community needs. Sustainable waste management requires both immediate improvements in infrastructure and long-term strategies for behavior change through education. This dual approach can lead to more comprehensive and lasting improvements in waste management. In summary, the survey responses from Butare Cell regarding waste management priorities are consistent with broader findings in Africa. The emphasis on improving waste collection infrastructure and public education highlights effective strategies for enhancing waste management and addressing community needs.

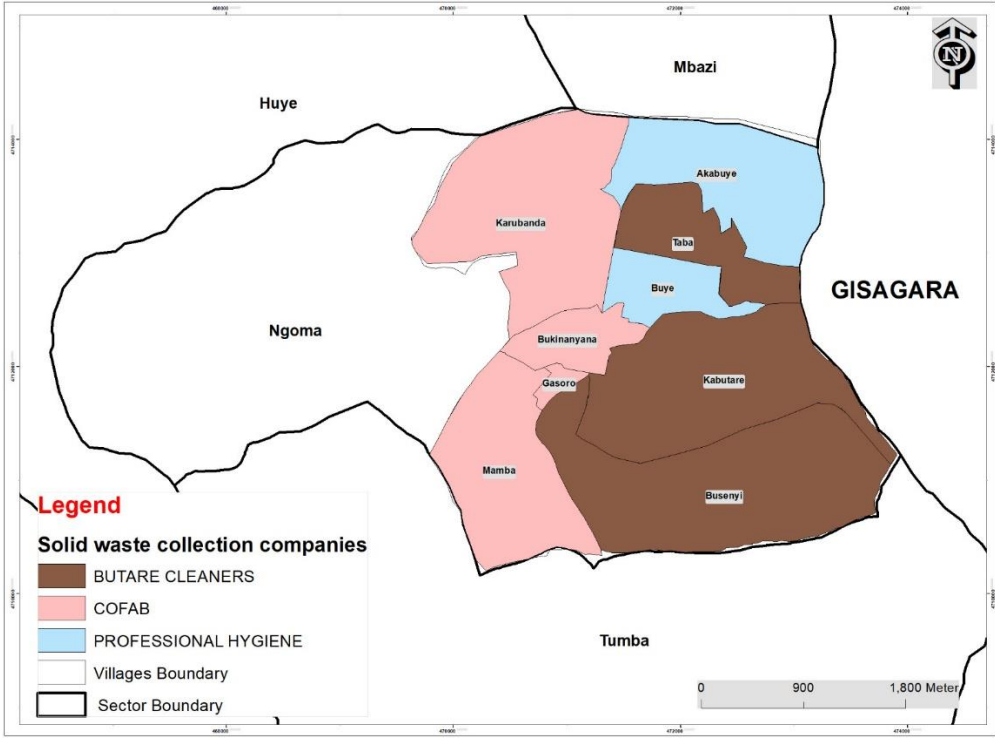


Figure 12: Spatial distribution of waste collection companies

Source: Author, 2024

4.4.2. The role of community to improve waste management

Table 13: Role of community to improve waste management

How can the community play a more active role in improving waste management in Butare cell?	Percent
Organizing neighborhood clean-up events	70.0
Promoting composting initiatives	13.0
Holding community discussions on waste reduction strategies	17.0
Total	100.0

Source: Author, 2024

Organizing neighborhood clean-up events (70%) and holding community discussions on waste reduction strategies (17%) are seen as effective ways for the community to participate in waste management. Promoting composting initiatives (13%) can further reduce the amount of waste sent to landfills and improve soil health.

In Nairobi, Kenya (UN-HABITAT, 2010) highlighted the effectiveness of community clean-up campaigns in raising awareness and improving local waste management. Similar findings were reported in Accra, Ghana, where organized clean-up activities were linked to enhanced community engagement and cleaner neighborhoods (Taiwo, 2009). The high percentage (70%) of respondents supporting neighborhood clean-up events aligns with previous studies that emphasize the benefits of community involvement in waste management. Clean-up events can foster a sense of community ownership, reduce litter, and encourage collective action. This suggests that such initiatives are a well-received and practical approach to improving local waste management practices.

4.4.3. Key elements of an effective solid waste management system

An effective solid waste management system in Butare cell should integrate these key elements as shown in table 21 to ensure sustainable practices, environmental protection, and community well-being. By prioritizing proper waste collection and disposal, public education, integrated approaches, regulatory enforcement, waste reduction, and recycling, the city can work towards minimizing environmental impact and promoting a healthier living environment for its residents.

Table 14: Key elements of solid waste management system

Key elements of an effective solid waste management system	Percent
Integrated waste management approach	15.0
Waste reduction and minimization	10.0
Resource recovery and recycling	7.0
Proper collection and disposal of waste	30.0
Public education and awareness	25.0
Effective enforcement of regulation	13.0
Total	100.0

Source: Author, 2024

In Lagos, Nigeria, found that proper waste collection and disposal are critical components of effective waste management. Similarly, research in Nairobi, Kenya, emphasized that improving waste collection services was a key focus for managing waste effectively (UN-HABITAT, 2010). The 30% of respondents prioritizing proper waste collection and disposal aligns with findings from other studies, underscoring the foundational role of effective collection systems. This suggests that enhancing waste collection infrastructure and practices is essential for addressing waste management challenges. In Accra, Ghana, Amoah et al. (2009) highlighted the importance of public education in promoting proper waste management practices. Similarly, in Dar es Salaam, Tanzania, community education was identified as a key factor in improving waste management outcomes (Mchome et al., 2012). The 25% focus on public education and awareness reflects a recognition of its importance in fostering better waste management behaviors. Increased investment in educational programs can lead to greater community involvement and improved waste management practices.

In Johannesburg, South Africa, the Department of Environmental Affairs (2013) emphasized an integrated approach to waste management that includes recycling, composting, and waste-to-energy. This holistic strategy is seen as crucial for managing waste sustainably. The 15% of respondents advocating for an integrated waste management approach highlights a broader perspective on waste management. This approach can enhance sustainability by reducing waste volume and improving resource recovery. Implementing such strategies can lead to more effective waste management solutions.

A study in Kinshasa, Democratic Republic of Congo by (Kang et al., 2023) found that enforcing waste management regulations was crucial for ensuring compliance and improving waste management practices. Similarly, research in Nairobi, Kenya, highlighted the need for strong regulatory frameworks (UN-HABITAT, 2010). The 13% of respondents emphasizing enforcement aligns with the need for robust regulatory mechanisms. Effective enforcement ensures that waste management laws and standards are followed, which is critical for maintaining a high standard of waste management and addressing illegal dumping.

In Lagos, Nigeria, efforts to reduce waste generation through source reduction were emphasized as part of a comprehensive waste management strategy (Yakubu, 2017). This approach helps to minimize the volume of waste and reduce the strain on waste management systems. The 10% focus on reducing and minimizing waste generation reflects an important aspect of waste management. Addressing waste generation at the source can significantly reduce the overall waste burden and improve sustainability.

In Johannesburg, South Africa, the importance of recycling and resource recovery was highlighted as a key component of waste management. Resource recovery helps reduce landfill use and supports circular economy practices (Govender et al., 2023). The 7% of respondents emphasizing recycling and resource recovery suggests a growing awareness of the benefits of these practices. Increasing support and infrastructure for recycling can help divert waste from landfills and recover valuable materials.

The diverse priorities reflect the need for a multi-faceted approach to waste management. Combining proper collection, public education, integrated management, enforcement, waste reduction, and recycling can create a more effective waste management system. The emphasis on proper collection and public education suggests that investing in these areas can lead to significant improvements. Enhanced waste collection systems and educational programs can address immediate waste management challenges. The support for an integrated waste management approach highlights the importance of adopting comprehensive strategies that include recycling, composting, and waste-to-energy. This can lead to more sustainable waste management practices. Effective enforcement of waste management regulations is crucial for ensuring compliance and improving overall waste management.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

This study assessed the effectiveness of solid waste disposal on urban environmental management in Butare cell, focusing on the practices, challenges, and opportunities for improvement. The findings reveal significant variability in waste collection services, with many residents not receiving regular collection despite municipal subsidies. Recyclable materials are prevalent throughout the city, yet there are no established recycling facilities, and reusing activities are minimal. The lack of transfer stations and the practice of burning or dumping waste highlight the need for improved infrastructure and processes. The study also identified poor management systems, inadequate equipment, and a lack of trained personnel as key challenges in the solid waste sector. Public awareness and participation in waste management are also notably low, contributing to ineffective waste-handling practices.

5.2. Recommendations

Based on the study's findings, the following recommendations are proposed to improve the solid waste management system in Butare cell. These recommendations aim to enhance infrastructure, increase public awareness, and improve operational efficiency.

5.2.1. Recommendations for Solid Waste Management Practice

1. Local Government and Municipal Authorities:

To address the challenge of long distances to the Sovu landfill, local authorities should consider setting up smaller, decentralized waste disposal facilities or drop-off centers within closer proximity to residential areas. This would reduce the transportation burden on households and encourage the use of formal disposal services.

2. Environmental Protection Agencies

Environmental protection agencies should enforce existing regulations more strictly to reduce informal dumping and burning practices. This could involve regular monitoring and imposing fines or penalties for illegal waste disposal.

3. Initiate Community-Based Waste Management Programs: NGOs and CBOs should engage communities in waste management by organizing neighborhood clean-up events, promoting composting initiatives, and setting up local recycling programs. These efforts can reduce the

volume of waste that needs to be transported and disposed of at centralized facilities and foster a sense of community responsibility.

4. Invest in Waste Management Technology: Private companies could invest in innovative waste management technologies, such as mobile waste collection units or waste-to-energy facilities, to improve efficiency and reduce waste. Partnerships between the private sector and local authorities can facilitate these investments.

5.3. Future Research Directions

To further improve solid waste management in Butare cell and beyond, future research should focus on:

Evaluating the long-term impacts of implemented waste management strategies on environmental quality and public health.

Investigating the economic viability and sustainability of various recycling technologies suitable for the local context.

Analyzing the social dynamics influencing public participation in waste management programs.

Assessing the potential for integrating advanced waste treatment technologies, such as waste-to-energy, in the local waste management infrastructure.

By addressing these areas, researchers and policymakers can develop more comprehensive and effective strategies for managing urban solid waste, ultimately leading to more sustainable and resilient urban environments.

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ANNEXES

APPENDIX 1. INTRODUCTION LETTER

Dear Sir/Madam,

I am Bizimana Alain, a student at the University of Rwanda, Nyarugenge Campus, Geography Department pursuing a Master of Geo Information Science for Environmental and Sustainable Development. I am doing my research to assess the Effectiveness of Solid Waste Disposal on Urban Environmental Management. A Case Study of Butare Cell, Ngoma sector, Huye district. This Questionnaire is prepared for an academic purpose to fulfill an MSC degree in Geo-Information Science for Environmental and Sustainable Development. Specifically, the objective of the study is to assess the challenges related to solid waste disposal management in Butare Cell, analyze the methods of solid waste collection in the study area, and examine the methods of solid waste transportation in Butare Cell.

This study aims to explore how current waste disposal practices impact urban cleanliness and resident well-being in Butare Cell. Your input as a resident is highly valued. By sharing your insights, you will help us identify strengths and weaknesses in the current waste collection and disposal system, understand how waste management practices impact the environment and public health in Butare Cell, and develop recommendations for improving waste disposal and promoting a more sustainable urban environment.

The findings of this research will be used to inform local authorities in developing more effective waste management strategies, identify areas for potential improvement in Infrastructure and services, and promote public awareness about the importance of proper waste disposal. By participating, you will be making a significant contribution to a cleaner, healthier, and more sustainable future for Butare Cell. Therefore, I prioritize your privacy. I understand your concerns about sharing personal information. Please be assured that all data collected will be treated with the greatest confidentiality. We will anonymize your responses whenever possible and will never share your personal information with any third party. Your participation in this survey will be strictly confidential. Your data will be anonymized and used solely for this research. Your trust is crucial to us, and we are committed to protecting your privacy throughout this process.

"Thank you very much for your esteemed and fruitful participation in the study.

Name and signature

.....

APPENDIX 2. Questionnaire Survey for Households, Private services, and local leaders

Instructions

Please tick (✓) to fill in the appropriate box and provide detailed responses where necessary.

SURVEY QUESTIONNAIRE FOR THE LOCAL POPULATION

IDENTIFICATION OF RESPONDENT

Gender: Male

Female

Marital status: Single

Married

Widowed

Divorced

Age: 18-29

30-39

40 beyond

QUESTIONS

What is the size of your family?

1 person

6-7 persons

2-3 persons

above 7 persons

4-5 persons

What is your highest level of education?

No education

primary education

Secondary education

High Education

Other

What is your occupation?

What is your monthly family income?

Below 35,000 RWF

35,000 - 50,000 RWF

50,000 - 100,000 RWF

100,000 - 200,000 RWF

Above 200,000 RWF

How long have you been residing in Butare Cell?

Below 1 year

1-5 years

Above 5 years

Section 1: Household Waste Generation and Disposal

A. Which of the following types of waste do you generate in your household? (Select all that apply)

- Food scraps
- Paper products
- Plastic packaging
- Glass and metal containers
- Hazardous materials (e.g., batteries, paints, chemicals)
- Other

.....

B. Approximately how much Kilogram of waste does your household generate per week?

- Less than 5 kg
- 5-10 kg
- 10-20 kg
- More than 20 kg

C. How do you currently dispose of your household waste?

- Door-to-door collection by waste management service provider
- Community collection point
- Burying waste in your backyard
- Burning waste
- Other (please specify)
.....

D. What are the biggest challenges you face in managing your solid waste?

- Insufficient collection frequency
- High cost of collection services
- Lack of awareness of recycling and composting options
- Difficulty in separating different types of waste.
- Lack of access to disposal facilities
- Other (please specify)
.....

E. What do you think are the main reasons for the current state of solid waste management in Butare Cell?

- Inadequate infrastructure
- Lack of funding
- Lack of public awareness
- Ineffective regulations

- Other (please specify)

Section 2: Awareness and Perceptions of Solid Waste Management

What sources of information do you rely on to learn about waste management?

Television radio community meetings social media

Other

Section 3: Suggestions for Improvement

A. What specific actions do you think the government should take to improve waste management in Butare Cell?

- Expanding recycling options
- Improving waste collection services
- Implementing public education campaigns to promote waste reduction and proper disposal.

B. How can the community play a more active role in improving waste management in Butare Cell?

- Organizing neighborhood clean-up events
- Promoting composting initiatives
- Holding community discussions on waste reduction strategies
- Other

.....

C. What are the key elements of an effective solid waste management system?

- Integrated waste management approach
- Waste reduction and minimization
- Resource recovery and recycling

- Proper collection and disposal of waste
- Public education and awareness
- Effective enforcement of regulations

Thank you for your time and your participation!

QUESTIONS FOR PUBLIC/PRIVATE SERVICES

- What is the name of your organization?

.....
.....
.....
.....

- Can you tell me the approximate number of employees working within your organization?

.....
.....
.....
.....

- What is your organization's annual budget allocated for waste management operations?

.....
.....
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- Could you elaborate on the specific areas of waste management that the department focuses on?

- Waste collection services (residential and commercial)
- Recycling programs and facilities

- Public education and outreach initiatives related to waste reduction and proper disposal.
- Management of landfills or waste disposal sites

➤ What is the nature of your organization's involvement in solid waste disposal in Butare Cell? (e.g., waste collection, waste transportation, waste treatment, waste recycling)

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➤ How long has your organization been operating in Butare Cell?

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➤ What are the primary responsibilities of your organization about solid waste disposal in Butare Cell? collecting waste from households, transporting waste to disposal sites, managing waste treatment facilities, operating recycling programs

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➤ What specific services does your organization provide to manage solid waste in Butare Cell? (Please provide a detailed list of services)

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➤ What is the coverage area of your waste collection services (e.g., specific sectors or regions)?

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➤ How do you measure the effectiveness of your waste management practices?

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Section 1: Evaluating Current Practices and Effectiveness

1. Effectiveness of Waste Management Practices

- How would you rate the effectiveness of your organization's current waste management practices in Butare Cell?

Very effective Moderately effective Ineffective

2. Challenges and Opportunities in Solid Waste Management

- What are the main challenges that your organization faces in managing solid waste in Butare Cell?

Limited infrastructure Insufficient funding public apathy
Lack of effective waste management policies

- How has your organization adapted to or overcome these challenges?

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Section 3: Recommendations and Future Directions

3 . Priorities for Improvement

- What are the most urgent areas for improvement in solid waste management in Butare Cell? enhancing waste collection, promoting waste reduction, and expanding recycling programs

- What specific recommendations does your organization have for addressing these priority areas?

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- What role do you see your organization playing in implementing these recommendations?

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4. Sustainable Waste Management Practices

- How is your organization incorporating sustainable practices into its waste management operations? using eco-friendly waste collection vehicles, adopting renewable energy sources, and reducing waste generation

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- How can your organization contribute to promoting a culture of sustainability and environmental responsibility among residents and businesses in Butare Cell?

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5. What new technologies or innovations is your organization considering for waste management?

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Thank you for your time and your participation.

INTERVIEW QUESTIONS FOR LOCAL LEADERS

Section 1: Background and Understanding

1. What specific responsibilities do you have about waste management in Butare Cell?

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2. How often do you engage with the community on issues of waste management?

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3. What are the primary sources of solid waste in Butare Cell?

- (i) Household waste (ii) Commercial waste (iii) Industrial
(iv) Agricultural waste (v) Other (please specify).....

Section 2: Evaluating Current Practices and Identifying Challenges

4. How do you track the amount of waste generated in Butare Cell? Are there any weight measurements or volume estimations done?

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5. a. What are the main challenges faced by local authorities in managing solid waste disposal in Butare Cell?

- (i) Lack of adequate infrastructure and equipment
(ii) Insufficient funding for waste management initiatives

(iii) Public apathy and lack of participation in waste management ef

(iv) Ineffective waste management policies and regulati

(v) Other (please specify)

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b. How have these challenges hindered the effectiveness of solid waste disposal in Butare Cell?

(i) Significant hindrand (ii) Moderate hindran (iii) Minimal hind ce

C. Can you provide examples of recent initiatives that have been successful or unsuccessful?

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Section 3: Recommendations for Improvement and Future Directions

7. Prioritizing Solid Waste Management Initiatives

➤ Which aspects of solid waste disposal in Butare Cell require the most urgent attention and improvement?

(i) Strengthening waste collection and transportation syst

(ii) Enhancing waste reduction and recycling programs

(iii) Establishing waste-to-energy facilities

(iv) Implementing comprehensive waste management education and awareness can

(v) Other (please specify)

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Thank you for your time and your participation.